THE

METALS IN ANTIQUITY.

(The Huxley Memorial Lecture for 1912.)

BY

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[WITH PLATES XXV–XXIX.]

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THE METALS IN ANTIQUITY.

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The only records available to us of man before he became acquainted with metals are written in the remains which have been unearthed from time to time in the caves or sites where he led a precarious existence, in the districts over which he wandered, in the mounds or places in which he was interred, or in the debris of terrestrial denudation, river gravels and the like. The same, too, is true of later man during the early metal ages. But as time rolls on and the ruder arts and usages gradually develop into a civilization approaching, and indeed in some respects equalling, or even excelling that of our own day, the evidence afforded by the remains is supplemented by those records of the past which we find in the clay tablets of Chaldaea and Assyria, the papyri and inscriptions of Egypt and the literature of ancient Greece and Rome.

As regards metals, however, the chief and often the only evidence on which reliance can be placed is that derived from the same source as in the ~~pre~~-metal ages, viz., the objects and articles which excavations bring to light. It is too often assumed that before man became acquainted with metals he was a mere savage but little superior to the wild animals of his time, but that this view is entirely erroneous, certainly as regards late neolithic man, is incontestably proved by the evidence presented so clearly to us by the vestiges which have been laid bare of his culture and mode of life. He was a farmer, kept domestic animals, was acquainted with the arts of weaving, the manufacture of pottery, his dwellings were constructed with considerable skill, and at his death he was buried with ceremonial rites. Such were the men who were the discoverers of metals and the first metallurgists. They were, in fact, men possessing greater intelligence and a higher culture than is usually attributed to them, and if we ourselves were deprived of metals I hardly think that we could surpass them in the exigencies or even the arts of everyday life.

Hence it was that they were able to make full use of the new discovery of metals and at once to produce weapons and implements of bronze as well suited to their special needs as any we could make of that alloy at the present day.

Of many of their implements it has been truly said that "they are works of art, a rude and primitive art it must be confessed, but as full of meaning in its simple expression as the Venus of Melos or the friezes of the Parthenon."

As regards the order in which the metals were discovered, it is self evident that it cannot have been the same in every region, as metallic ores are very capriciously distributed in the world : in a given locality it frequently happens that one may be abundant and the others altogether absent. Further, the metals which occur native, *i.e.*, as metals in nature, *viz.*, gold, copper, silver, and iron, with the exception of the first, are even more irregular in their occurrence than ores.

It is extremely probable, if not absolutely certain, that neolithic man would first become acquainted with the "native" metal gold, as it is of almost universal occurrence in the sands and gravels of rivers and in superficial alluvial deposits.

It is, however, one of the most worthless of metals for the practical purposes of life and especially for the simple requirements of Stone Age man. Moreover, in the small particles in which it usually occurred, for no pieces of even moderate size have come down to us from prehistoric times, it could not be applied to any use by early men, as they would be unacquainted with the art of melting, by which alone these particles could be converted into lumps ; whilst if any lumps had been found, although capable of being fashioned by simple hammering into many forms, yet these, on account of the softness of the metal, could have had no useful applications except as personal ornaments.

Unlike gold, copper is found in the metallic state in very few localities but in greater abundance.

The chief of these are the Lake Superior district, Chili, Yunnan (China), Bolivia, Burra Burra (Australia), and Cornwall. In the first named, notably in the Lake Superior district, it occurs in large quantities, and the masses have been rudely worked there from very early times ; it was, hence, the first metal to be known and used by the men of these regions.

Silver is of rare occurrence as metal in nature and is not found like gold in river sands and gravels, but in mineral veins or lodes, from which it can only be obtained by mining. Hence, the metal was unknown during the Early Metal Age.

Iron, in the condition of metal, occurs native in two forms, one of cosmic and the other of telluric origin. The former as meteorites (siderites) has a limited distribution, the greater number occurring in North and South America.

As regards the latter the only occurrence of masses of undoubted telluric origin are those found by Nordenskiold at Ovifak, in Greenland.

The Eskimo, as is well-known, fashioned knives, etc., from the Ovifak masses, and iron was hence the first metal known to them.

It is, however, manifest that the discovery of the native metals was quite insufficient to affect to any great extent and in but limited areas the old Stone Age culture. No advance beyond that stage of culture could be made until the art of extracting metals from their ores and of melting and casting them had been discovered, by which implements and weapons could be fabricated, which would not only satisfy more perfectly the needs of the individual and tribe, but facilitate their expansion and create new ones.

In fact, until man had made that discovery, although in a few exceptional

localities he may have been acquainted with native metals, he still had not passed out of the Stone Age.

Why this discovery was so long delayed and the Age of Stone continued for such a vast period it is impossible for us to conjecture, especially so when we consider that the ores which would be within reach were the oxide ores occurring on the surface of the ground, which are the most easily reducible of all minerals.

When a lump of any of these ores, either of copper, carbonate, tin-stone, or brown iron ore or hæmatite, which, by chance, had been one of the ring of stones surrounding the camp or domestic fire and had accidentally become embedded in its embers, it would undoubtedly be reduced to metal.

The cakes or lumps so produced would naturally attract the attention of primitive man, and if he attempted to fashion them, as he was accustomed to do in making his implements of stone, he would them become acquainted with their curious properties of malleability and toughness, which were wanting in his customary materials, and so be led to apply them to practical use.

It was thus, in my opinion, that man first became really acquainted with metals. The camp fire was, in fact, the first metallurgical furnace, and from it, by successive modifications, the huge and complicated furnaces of our own days were gradually evolved.

The first stages in this evolution were easily reached, a cavity would be formed in the hearth of the fire for the reception of the molten or reduced metal and this would be made deeper and wider as time went on and larger quantities of metal were needed.

In Japan, when I arrived there in 1872, the evolution of the smelting furnace had only reached this stage. In fact, no appliance of the primitive metallurgy of the Bronze Age could have been either simpler in shape or ruder in construction than the furnace then in use and even still employed at many small mines.

It consists merely of a hole in the ground, yet by means of it, until a few years ago, all the copper, tin and lead produced in the country was obtained. Plate XXV, Fig. 2, represents the smelting of tin.[1]

At Laurion, in Greece, in the earliest times of metallurgical work in that metalliferous region, a further stage of development had been reached in the evolution of the smelting furnace.

The smelting cavity or hearth was raised above the ground and enclosed within a low wall of stone.

The first stage in the production of metal having been reached, there still remained to early man the most important problem of utilizing the lumps which his camp fire had yielded. For their utilization in the case of iron, as we will see later, nothing further was required than to remove them from the fire and hammer them on a large stone with a stone hammer, as is still done in several localities in Africa.

[1] *Archaeologia*, vol. lvi, p. 294. Reproduced by permission of the Society of Antiquaries.

In the case of copper and its alloys, however, remelting was necessary, and to effect this the primitive metallurgist of those remote times simply made a miniature copy in clay of the cavity in his camp fire in the form, at first, of a shallow dish or saucer, embedded it in the hearth of the fire, piled the fuel above it, and so obtained a small quantity of molten metal. Further, just as he had deepened the cavity in the hearth so that it might contain more metal, in like manner he gradually increased the depth of his shallow dishes until they became veritable crucibles of cup-like forms, from which, in fact, the crucibles of the present day have been evolved.

During the early stage of the Metal Age, the ores from which copper and sometimes its alloys, with tin, nickel, antimony and arsenic, etc., were obtained were, as I have already pointed out, easily reducible surface ores, occurring in the beds of streams or on mountain sides.

Mining operations were of a decidedly later period, when considerable advance had been made in the use of metal, yet it is a curious fact that even then, hammers and mauls of stone and picks of deer horn were still employed as tools by the ancient miners in the Asturias, at Rio Tinto, the Atlas district, Mitterberg in Austria, Lake Superior district, Mexico, and Chili.

At first sight they would seem to be singularly inefficient tools for breaking out the ore from hard rock, but the men of that time had evidently observed that stones are splintered by fire, and had applied that knowledge to aid them in their mining operations. This is indisputably proved by the remains of charred wood and charcoal which have been found at the end of the burrows in North Wales, Cardiganshire and the Mitterberg in Upper Austria and other places. This method of mining by the aid of fire was conducted as shown in Plate XXV, Fig. 1.[1]

Billets and faggots of wood were piled up against the face of the ore in such a manner that when set on fire the flame should play against the mineral mass to be disintegrated, the result being that a considerable quantity of the ore was splintered off in flakes, and the remainder to a certain depth was so much shattered that it could easily be detached by almost any kind of tool.

We will now proceed to the consideration of the respective metals known and in use in antiquity, and here I may say that great as has been the advancement in metallurgy since prehistoric times, yet in many localities the rude and primitive methods still survive.

In Japan, as I have already pointed out, this was notably the case until recent years, where all the useful metals—copper, lead, tin, and iron—were extracted by processes and appliances differing but little from those in use during the infancy of metallurgy, when men had just emerged from the Age of Stone.

It is owing to these survivals that we are able to interpret the meagre relics of that remote period, also to throw light on the imperfect accounts of Strabo and Pliny and other classical writers of the metallurgic arts as practised in later days.

[1] *Archaeologia*, vol. lvi, p. 269. Reproduced by permission of the Society of Antiquaries.

Copper.

Copper is found native as metal in but few localities, the most notable being the Lake Superior district, where it occurs in large quantities, and has been in use from very early times. It was hence the first metal to be utilized for practical purposes by the men of these regions.

In the Lake Superior district it is found in masses, frequently of enormous size. That shown in Fig. 1[1] weighs 3 tons. It was taken from an ancient pit, 16½ feet deep, and exhibits the marks of stone hammers or axes. Another mass, measuring 10 feet by 3 feet by 2 feet, and weighing over 6 tons, was found along with numerous stone hammers. It had been pounded with these until every projecting part had been broken off.

FIG. 1.—MASS OF NATIVE COPPER. LAKE SUPERIOR.

Many axes, lance heads, and other objects of a remote age, all fashioned from the native copper by simple hammering, have been unearthed from time to time.

It is extremely curious that the men of this region never discovered the art of melting the metal and casting it in moulds, so that although acquainted with metal they still remained in the Stone Age of culture.

In other regions of the world where man had discovered the art of reducing metallic ores to metal, the copper ores were oxidized copper ores, sometimes associated either with ores of tin, antimony, arsenic, nickel, or silver, in small amounts, or with tin ores in considerable quantities. In the former case, copper would be obtained on melting them, and would contain one or more of the metals enumerated in greater or less proportions, varying with the composition of the ore. In the latter case bronze would be produced. Hence, in Hungary, where the copper ores are associated with antimony ores, the early implements contain

[1] *Jour. Royal Anthrop. Inst.*, vol. xxxvi, p. 12.

antimony up to 4½ per cent., an alloy resembling bronze in many of its physical properties. Similarly, implements in Ireland and Egypt, sometimes contain 2 to 4 per cent. of arsenic, and in Germany from 2 to 4 per cent. of nickel.

In England, where copper and tin ores are so commonly associated, as in Cornwall, the earliest implements are of bronze.

Owing to the non-discovery of tin, or copper ores containing it, in early times in Ireland and their absence in Cyprus, the implements of the Early Metal Age in these localities are of copper, and this at a time when Central Europe was in the Bronze Age.

The fact is that the first metal obtained by primitive man by smelting ores depended on their composition, and in the localities where tin did not occur it was a more or less impure copper. It does not, hence, follow that there was a true Copper Age in Europe, although in Ireland, from the abundance of copper implements which have been found there, there was evidently a stage of transition between the Age of Stone and the Age of Bronze, during which copper was in use.

That this stage overlapped to a very considerable extent the Age of Bronze in Central Europe is distinctly proved by the copper halberds with rivets, described by Coffey (*Proc. R.I.A.*, 1908, pp. 94 *et seq.*). These copper halberds and the use of rivets show a marvellous advance in the art of metal working; their forms are those usually—and, I think, correctly—attributed to the Later Bronze Age in Europe, and they cannot have been originally invented in Ireland. The bronze implements of Europe must hence have been copied in Ireland, and no tin or stanniferous copper ores having then been found there, copper had to be employed.

In Africa, apart from Egypt, there are so far no evidences of an intermediate stage between the use of stone and that of iron, notwithstanding the abundant deposits of copper and tin ores.

In Britain, suitable ores for the production of bronze were at hand, hence bronze and not copper was the first metal to be employed.

One of the earliest implements, a small flat axe found by Greenwell, together with a flint knife, a long flint scraper and some flint chippings in a barrow in Yorkshire, have been adduced by Dr. Much in "Die Küpferzeit in Europa" being misled by its form, as evidence of a Copper Age in Britain, but on analysis I found it to contain 10·68 per cent. of tin.

As I have already stated the first metallurgical furnace was the camp fire, and as time went on it gradually developed into the simple "hole-in-the-ground" furnace, which still survives in Japan.

The process of smelting, too, in Japan is of the simplest nature, and it also is a survival from a very remote period.

It is, therefore, in the highest degree probable, if not absolutely certain, that the process of smelting followed by the men of the Bronze Age was identical with that not yet extinct in Japan. It may be remarked further that the evidence afforded by the shape, size, and structure of the lumps of copper which have been found in the founder's hoards of the Bronge Age entirely supports this view.

The furnace is simply a hemispherical cavity in the ground without enclosing walls of any kind.

It is worked with an artificial blast of air, but when shallow the wind alone would be sufficient to obtain the temperature necessary for the reduction of copper ores to metallic copper.

The lumps of copper from founder's hoards are always fragments of rudely disc-shaped cakes of about 8 inches to 10 inches in diameter, and 1½ inch in thickness, having the largely columnar fracture of copper when broken near its solidifying point.

They show that the furnace was simply a small shallow hole or hearth scooped in the ground, about 10 or 12 inches in diameter, and that the operation of smelting must have been conducted as follows :—

A small charcoal fire was first made in the hearth, and when this was burning freely a layer of ore was spread over it, and upon this a layer of charcoal, then alternate layers of ore and charcoal were added in sufficient quantity to yield a cake of copper. The fire was doubtless urged by the wind alone in the earliest times, but later by some kind of bellows.

When all the charge had melted, the unburnt charcoal and the slag were raked off. The metal was not laded out, but was allowed to first solidify, and at the moment of solidification was rapidly pulled out and the cake broken up at once on a large stone. In Korea, at the copper mine of Kapsan, this primitive method of removing the copper from the furnace still survived when I travelled through that country in 1884.

The alloys of copper and tin during the Early Metal Age, and even somewhat later, were obtained not by melting together copper and metallic tin but by the reduction of oxidized copper ores containing tin-stone, or of copper ores to which tin-stone was added.

As the statement made some time ago by several Continental metallurgists has been recently repeated that when a copper ore containing tin ore is smelted the tin does not unite with the copper but passes into the slag, I may be permitted to give here a brief account of the experiments I have already described before the Institute which completely disproves it.

"A furnace of the simplest form, merely a hole in the ground, was constructed in my laboratory at the Royal School of Mines. The fuel used was charcoal. A mixture of copper ore (green carbonate) and tin-stone was smelted in it, and a copper-tin alloy, a bronze containing 22·0 per cent. of tin was obtained.

"A description of the working of one charge will suffice. The charge consisted of the following materials :—

Copper ore (copper carbonate) containing 30 per cent. copper	15 lbs.
Tin ore (cassiterite) containing 20 per cent. tin ...	10 „
Limestone	7½ „
Charcoal	10 „

"The charcoal and limestone were coarsely ground and mixed with the ores.

"The furnace cavity was filled with charcoal, which was also piled above it to a height of about 2 or 3 inches. When the charcoal was well alight a layer of the charge was spread over its surface, then another layer of charcoal, then alternate layers of the charge and of charcoal were added so as to form a conical heap. A gentle blast was then started through a 1-inch blast pipe, and when the charge began to sink down into the furnace cavity it was slightly increased. When the whole of the charge and fuel had sunk down into the furnace the blast was stopped, the slag and remaining fuel removed, and the metal allowed to solidify. The metal was analysed and found to contain 22·0 per cent. of tin."

The experiment was repeated several times, and in every case copper-tin alloys were obtained. These experiments prove indisputably that when a copper ore containing tin ore was smelted by primitive man, a bronze consisting of copper and tin was obtained, and affords a complete refutation of the statements that such ores will only yield copper and not a copper-tin alloy. It shows, further, that these statements are not based on any experimental work, but have been erroneously deduced from the methods of smelting in use at the present time, which differ *in toto* from those which were practised, and in fact alone possible, in the earliest days of metallurgy.

We will now proceed to the consideration of the alloys, accidental and intentional, which were employed in prehistoric times. Here again I may be permitted to repeat what I have already stated before the Institute regarding poor tin bronzes, as the old erroneous views are still occasionally set forth.

"We will first consider the alloys which were the accidental result of smelting impure ores. In this category may be placed all those which contain less than about 1–2 per cent. of tin, although in exceptional cases a much larger percentage of tin may be accidental, as, for example, when the metal was obtained by smelting a copper ore rich in tin ore.

"Now, the presence of as little as 1–2 per cent. of *tin* has a marked effect on copper, especially on copper of the nature of that produced in primitive furnaces. In the first place, it confers a certain amount of hardness, not very great, but decidedly perceptible, which can be greatly intensified by hammering. Secondly it facilitates the production of sound castings with copper even when impure, which otherwise would be vesicular and useless.

"Hence certain copper ores, viz., those containing even small quantities of tin, would be used in preference to others for the extraction of metal for the manufacture of implements.

"The small proportion of tin present in some implements has been supposed by several archaeologists to be due to the oxidation or volatilization of the metal in a richer alloy by remelting, as in recasting worn or broken articles. Loss by oxidation or volatilization, however, is entirely governed by the conditions under which the remelting takes place, and there can be no fixed rule regarding it. Its amount depends, in the first case, on the extent to which the surface of the metal has been

exposed to the air during melting and when molten; and in the second case, on the temperature to which the alloy has been raised.

"In the rude furnaces of prehistoric times, when the metal was melted in clay vessels over which the fuel, charcoal, was piled, its surface would be but little exposed to the air; moreover, the temperature of the fire would not be excessive, so that there would not be much loss of tin in remelting, and the low percentages present in poor tin bronzes are not caused by this operation."

It has been frequently stated that the alloy used by the men of the Bronze Age generally consists of copper and tin in the proportions of 9 to 1. I have hence compared the analyses, which have been published, with the following results:—

Early Weapons and Implements—57 Analyses.

In 25 the tin ranges from about 8 to 11 per cent.
„ 6 „ „ „ „ 11 „ 13 „
„ 26 „ „ „ „ 3 „ 8 „

Later. (Palstaves and Socketed Axes)—15 Analyses.

In 13 the tin ranges from about 4·3 to 13·1 per cent.
„ 2 „ was about 18·3 per cent.

Spear and Lance Heads.

In 5 the tin ranges from about 11·3 to 15·7 per cent.

Still later. Swords—23 Analyses.

In 14 the tin ranges from about 8 to 11 per cent.
„ 12 „ „ „ „ 12 „ 18 „
„ 7 „ is less than 9 per cent.

It is obvious, therefore, that these statements do not accurately represent the facts. And if we consider the different uses to which the implements or weapons were put, it is evident that no single alloy could be equally suitable for all. For certain uses an implement of copper, or of an alloy containing but little tin, would be efficient. On the other hand, for a sword or dagger certain physical properties are essential that are not needed for an axe; thus, whilst 10 per cent. of tin, or somewhat less, would be satisfactory for the latter, a higher percentage, say from 11 to 14, would be required for the former. It is worthy of note that these proportions appear to have been frequently attained, and for this the men of the Later Bronze Age are deserving of great credit as metallurgists and workers in metal.

The methods and appliances adopted by prehistoric man for the manufacture of his copper and bronze implements are of not less importance and interest than those he employed in the extraction of the metal from ores.

The relics of his work which have been unearthed from time to time afford clear and ample evidence of his methods of manipulation and the nature of his appliances. The metal obtained by his smelting operations, as we have already

seen, was not laded from the furnace whilst molten, but removed when it was in the act of solidifying.

It had hence to be melted either alone or, as the Bronze Age advanced, with the addition of tin ore or even metallic tin. This remelting was effected in rude dishes or crucibles, Plate XXVI,[1] made of clay, mixed sometimes with fragments of quartz to render them more refractory, but often only with finely cut hay or straw. None was able to withstand a very high temperature ; the fire was hence not placed below and around them as is the practice at present, but above and inside as follows :—

They were embedded in the ashes at the bottom of the furnace, which was merely a shallow depression in the ground, in such a manner that their bases and sides were protected from the intense heat of the fuel, their interior and upper edges only being exposed.

In consequence of this mode of heating the lower parts show but little traces of the action of a high temperature, whilst the upper edges and interior exhibit a fused or semi-fused structure.

The fuel used was wood and the charcoal produced during the process.

A temperature sufficiently high for melting the metal was obtained by the wind alone.

When the contents of the crucible had melted they were poured into moulds of stone, clay, or bronze.

In casting swords and daggers of bronze the moulds must have been of clay, and been heated to dull redness at the time when the metal was poured in—a method of casting which is still practised in Japan—as by no other means could such perfect casting of their thin blades have been obtained. The castings generally were hammered at the cutting edges, and it is to this hammering, and to it only, that the hardness of the cutting edges of both copper and bronze weapons is due, and not to any method of tempering. Much has been written about the so-called art of tempering bronze, supposed to have been practised by the men of the Bronze Age in the manufacture of their weapons ; the hardness is also said to be greater than can be given to bronze at the present day. I should like to correct this error, as it can only have arisen owing to its authors never having made any comparative practical tests of the hardness of bronze. Had they done so, they would have found that the ordinary bronze of to-day can be made as hard as any, in fact harder than most, of prehistoric times, by simple hammering alone.

The sources whence copper was derived in early times are widely distributed as the ores occur in greater or less amounts in every country in Europe and in many districts in Asia.

In Europe an important site of very early smelting is situated on the Mitterberg Alp in the Austrian Tyrol, where rude mining excavations and heaps

[1] *Jour. Royal Anthrop. Inst.*, vol. xxxvi, Pl. III.

of slag are associated with stone implements and with pottery closely allied to that found in the pile dwellings of the Mondsee.

At Monte Catini and Capanne Vechie in Tuscany, numerous shafts and narrow levels bear witness to the extent to which the rich upper parts of the veins of copper ore were worked by the Etruscans and probably earlier.

An ancient mine also occurs at Agordo in the extreme north of Italy near the borders of Tyrol.

In Cyprus mining debris and vast mounds of ancient slags are found in many localities. This is not surprising if we remember that Cyprian copper was not only famed in the time of Homer but was sent as tribute to Egypt several centuries earlier.

Greece had but few and unimportant deposits of copper ores, and remains of primitive workings occur only in Euboea and Macedonia.

Spain, on the other hand, more especially the southern coast, was rich in ores, which yielded copper at the very beginning of the Metal Age in that country.

In the present state of archaeological enquiry and mining explorations it would be presumptuous to assign to any locality the earliest production of copper from its ores, yet there is strong evidence in favour of the view that it was most probably in Cyprus, and, somewhat later, in the south-east of Spain, the Mitterberg in the Austrian Tyrol, the Tuscan region in Italy, and Britain, that the metal was first obtained in Europe.

In Asia, the extraction of copper from its ores, as we shall see later, dates from a period more remote than in Europe.

Considerable deposits of copper ore extend on the south of the Euxine from Sinope to Trebizonde, and are now being worked at several places on or near the sites of very ancient mines.

Similar deposits also occur in the island of Kalki near the western entrance of the Bosphorus, and at Sarigari on its north-eastern shores.

To the south of the Trebizonde region, and near Erzerum in Armenia, and also at Diarbekir in the upper basin of the Tigris, vast accumulations of mining and metallurgical refuse, and numerous excavations mark the sites of an important copper industry of a very remote date. Of considerable importance too were the mines of the Sinaitic peninsula, which were worked for copper in the time of Seneferu (about 3733 B.C.) and probably very much earlier. The remains there consist of huge heaps of waste material from the mines and slags from the smelting works. I may say that samples of the ore sent to England a few years ago, consisted of poor copper carbonates, the deposits having been exhausted of the richer ore by the old miners.

In India, in the Singhbhum district of Bengal and in the Madras Presidency, copper mining and smelting has been carried on from a very early period, and the number and extent of the ancient workings testify to the assiduity with which every trace of ore was followed up by the ancient miners. In Jaipur, too, are several very old mines consisting of tortuous galleries of great extent.

Copper ores are also found in several other districts but the above are the chief sites of prehistoric mining.

The materials for solving the problem, which is ever present with us, namely, the fixing of a relative chronology for the first use of copper by the various races or peoples of antiquity, are of a very fragmentary and too often of a decidedly nebulous character.

I may, however, be permitted to state briefly the present state of our knowledge on this important subject, and the conclusions which I think may not unreasonably be based on it.

Montelius[1] has proposed 2500 B.C. or a more remote period for the first part of the Bronze Age in Britain when copper was in use. This distinguished archaeologist[2] has also proposed 2100 B.C. for the small copper daggers in Northern Italy.

The copper of Cyprus, according to the inscriptions in the tomb of Thotmes III. (about 1500 B.C.) was received as tribute in Egypt in the form of vases and other vessels. They are of elegant design and workmanship and some are almost certainly of bronze. This undoubtedly indicates an advance in the metallurgic arts and skill in the working of metals that can only have been acquired after many centuries of practice. Hence, for this reason, 2500 B.C. cannot be considered as too early a date for the use of copper in Cyprus.

But further, if we examine the finds of bronze weapons made by Sir Arthur Evans at Knossos, to which the date about 2500 B.C. has been ascribed, and the copper for the manufacture of which was in all probability obtained from Cyprus, we are compelled, I think, to assign a not later date than about 3000 B.C. to the beginning of copper working in the island.

A very remote antiquity has been established for copper in Egypt by the discovery by M. de Morgan of copper articles in a tomb supposed to be that of Menes, which, if the supposition is a correct one, must be assigned to about 4400 B.C. And indeed there is no reason why copper objects of that early date should not have been in use by the ancient Egyptians, as we have already seen, the mines in the Sinaitic peninsula were being worked during the time of Seneferu (about 3733 B.C.). But long before actual mining operations were carried on, how long it is impossible to say, the metal must have been obtained by primitive methods from the surface ores. It is hence not unreasonable to assume that at least as early as about 5000 B.C. the metal copper was known and in use in Egypt.

Passing now to Chaldaea we are on less certain ground, yet the early inhabitants of Chaldaea were not unfavourably situated for obtaining copper as the deposits of the Tiyari district, and even those on the upper basin of the Tigris, must have been accessible to them, and a few objects of the metal have indeed been found which can be referred to as early a period as those of Egypt.

[1] *Archaeologia*, vol. lxi, p. 162. Reproduced by permission of the Society of Antiquaries.
[2] *Jour. Anthrop. Inst.*, vol. xxvi, p. 258 (Table).

The earliest of these to which a date can be assigned are,—a small copper figure bearing the name of King Gudea (about 2500 B.C.); and some figures from Tell Loh (Shirpurla) which served to support votive tablets associated with bricks said to bear the name of King Ur-Nina (about 4500 B.C.). The latter figures, as specimens of metal working, are much in advance of the Egyptian objects of similar approximate date. It would therefore seem that an earlier date than 5000 B.C. should be assigned to the first use of copper in the Chaldæan region.

In the Troad, copper was in use also in very remote times, owing to the proximity of the ore deposits near the Bosphorus and the not far distant and easily accessible mineral region on the southern shores of the Euxine. Amongst the objects of the metal found by Schliemann in the lowest stratum of the First Prehistoric City (3000 to 2500 B.C. Dörpfeld) at Hissarlik were four knives, two with rivet holes, and one gilt. Now it is important to note that the manufacture of these knives indicates a degree of metallurgical knowledge and technical skill, possessed by the artificers of that time, that could only have been attained long after the metal was first known. It would hence seem that copper must have been in use there not later than in Cyprus.

In China, archaeological exploration has been of a very limited character, as the examination of ancient burial sites is not only prohibited by the Government but is strongly opposed by the people. Hence we know practically nothing from actual finds of the Early Bronze Age culture of that ancient people. Copper ores occur in many places, but it is impossible to assign an even approximate date to the earliest workings, as they have not yet been systematically examined. If, however, we accept the date 2205 B.C. given in Chinese annals for the casting of the nine bronze tripod cauldrons, often mentioned in historical records, then the metal copper may have been in use as early as 3000 B.C. or even earlier.

From the foregoing brief statements of the dates relating to the Metal Age in prehistoric times it will be evident that very much still remains to be made out, and much more exploratory work must be done, respecting the intricate subject we have been considering,—the relative chronology of the discovery and application of copper—before we can say with certainty in what part of the world man first passed from the Stone into the Metal Age. It is not impossible that copper or an accidental alloy of the metal may have been obtained contemporaneously in different places.

It would, however, seem, on a review of the data available at present, that it is in a high degree probable that the ancient peoples of Chaldaea and Egypt were acquainted with copper at an earlier period than the races of Europe.

Tin.

It may be of interest here to quote the curious teachings of ancient Chinese philosophers as to the origin of the metal tin. "Tin," say they, "is produced by the influence of the feminine principle in nature, being classed between silver and lead. The metal arsenic generates itself in two hundred years and after another

two hundred years is converted into tin. Tin being a product of the feminine principal has tender qualities. When it is submitted to the influence of the masculine principle it is converted into silver. It is sometimes found that wine kept in tin vessels has a poisonous action on man, which proves that the arsenic had not been completely transformed into tin.

The metal tin, although of little practical use alone, was a most important metal to the men of the Early Metal Age by reason of the valuable properties it confers upon copper when alloyed with it to form the alloy bronze.

Notwithstanding its easy fusibility a high temperature is required for the reduction of its ore, yet, like copper, if, by chance, a lump of tin-stone became embedded in the fuel of the camp fire metallic tin would result.

In Cornwall the conditions for the production of the metal were especially favourable; the ore was undoubtedly abundant and subterranean mining operations were not required, as it was found either at the surface of the ground or at but little depth below it, disseminated through the old river gravels.

From the fusibility of tin and the comparative ease with which the ore is reduced, the metal must have been produced in Cornwall not very long after neolithic man settled there. And that this settlement took place in a very remote age is sufficiently proved by the megalithic monuments which are so numerous in that part of Britain. Further, the assumption that the earliest smelting can be traced to a Phoenician or any other foreign source is absolutely unsupported by any evidence.

It is, however, very surprising that no objects of tin have been found in association with either these early remains, or in the long barrows of a subsequent period, in the not far distant counties of Wilts and Dorset, or under any other conditions in undoubted association with the stone implements of the transition period.

The earliest mention of tin by a classical writer is found in Homer, where it is said to have been applied to the ornamentation of the shield of Achilles.

It is also mentioned in other passages of the *Iliad*, as in the description of the shield of Agamemnon and the chariot of Diomede.

The earliest finds, however, are of the Later Bronze Age. The metal does not lend itself to the manufacture of weapons or industrial tools. On the other hand, it is admirably adapted for simple ornaments, such as beads, rings, armlets, and the like, and was frequently so employed by the peoples of the pile dwellings in the lakes of Switzerland, France and North Italy and the early inhabitants of Persia.

Other minor uses were the ornamentation of pottery with strips of the metal and later the tinning of articles of copper and bronze.

Bronze flat axes in Scotland were occasionally tinned.

It is just possible that although the metal may have been long known in Cornwall, it may not have been regularly smelted from its ores until a knowledge of its value as a constituent of bronze or as an object of barter had

been ascertained by intercourse with the Mediterranean peoples through the medium of the tribes inhabiting the north-west and north of France.

As regards the making of bronze in the earliest part of the Bronze Age, there is no evidence to show that this was effected by the melting together of the metals copper and tin. Neither, as it has been demonstrated already, is metallic tin necessary, as when tin ore is melted with copper and charcoal, excellent bronze is obtained. Further, no metallic tin has been found in any of the founder's hoards which have been unearthed, except some roughly melted lumps of the metal, associated with two socketed celts, a broken palstave, a piece of bronze and a quantity of well-smelted copper at Kenidjack (W. Cornwall).[1]

It is true no tin ore has been found in the hoards, but this is not surprising as the ore is usually an earthy looking, pale brown material which would certainly be disregarded by the discoverers of the hoards unless they had specially looked for it.

No cakes of tin representing the earliest smelting of the ore have survived in Cornwall, but shallow holes in the ground containing charcoal and ashes, sometimes intermingled with fragments of the metal, have been discovered from time to time near ancient workings in the old river gravels. These are the remains of the furnaces of a very early, if not perhaps the earliest period. Unfortunately, neither sketches nor measurements appear to have been made of them by their explorers, and the descriptions which have been recorded are imperfect and wanting in exactness.

The furnaces seem, however, to have generally been merely narrow shallow trenches in the ground. The smelting operation was one of the simplest kind, and must have been conducted in the following manner:—

The trench, having been first lined with clay, was filled with brushwood, above which small logs of wood were piled. A light was applied, and as soon as the logs were burning fiercely and the trench was full of glowing embers, small quantities of ore were then thrown upon the top of the fire from time to time. More wood and ore were added, until the required amount of tin had accumulated in the trench. The fire was then raked away, and the tin laded out into a hole in the ground or into a clay mould near the furnace. Probably sometimes it was allowed to flow as it was reduced into a cavity at one end of the trench. The object of the trench, in addition to its use as a receptacle for the metal, was to hold a sufficient quantity of embers to reduce the portions of ore which had not been acted on in the upper part of the fire.

But the intercourse of the Britons with the traders from the more advanced races of the Mediterranean doubtless soon led to further modifications and improvements in their furnaces and mode of smelting.

The shallow hole then become deeper so as to "confine the fire," and was excavated near the edge of a bank of earth. The blast was no longer admitted over the edge of the cavity but through an opening just above the base, the molten tin being allowed to flow out, as it was reduced, through a still lower hole.

[1] *Archaeologia*, vol. xlix, p. 181. Reproduced by permission of the Society of Antiquaries.

The ruins of a furnace of this kind was found at Trereife near some very extensive ancient excavations for tin ore.

From the construction of the furnace, and from the occurrence of Roman pottery and other remains in the debris of others resembling it, I think there can be but little doubt that the furnaces in use during the period of the Roman occupation of Britain were of this form, although they had their origin in earlier times.

It is, however, very doubtful whether they were actually worked by the Romans themselves, as their sites are almost invariably found away from the coast, and there is an absence of sufficient evidence to show that the interior of Cornwall was ever completely subject to Roman rule. And the fact that there are no great military roads west of Exeter tends to indicate that the Britons there were at least

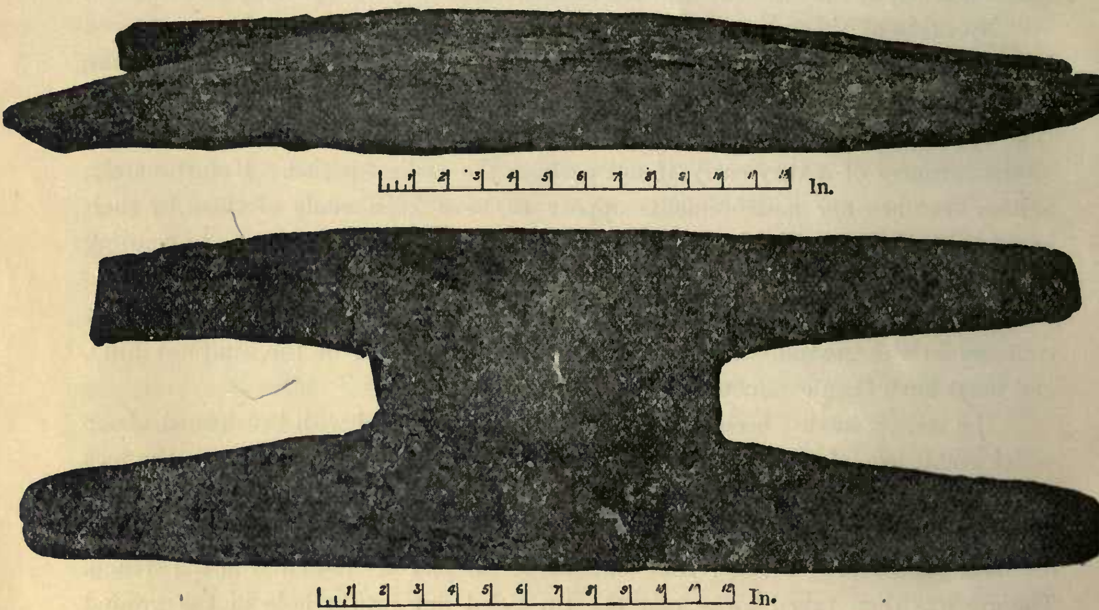

FIG. 2.—ANCIENT BLOCK OF TIN.

semi-independent, although they undoubtedly carried on a friendly intercourse for the purpose of trade with the Roman settlements on the east and on the coast.

One of the most interesting of the few blocks of tin which have been found is the well-known ingot, Fig. 2,[1] which was dredged up at St. Mawes near the entrance of Falmouth Harbour. It has two projecting arms at each end and measures 2 feet 7 inches in length over all. Its weight is about 158 lbs.

Some ingenious conjectures as to the object of casting tin in this form are contained in the pamphlet by Sir Henry James, mentioned in the footnote.[2] He suggests that this shape was chosen in order to facilitate transport. Thus the

[1] *Archaeologia*, vol. lvi, p. 300. Reproduced by permission of the Society of Antiquaries.

[2] Note on the block of tin dredged up in Falmouth Harbour, by Col. Sir Henry James, R.E., Director of the Ordnance Survey, London, 1863.

curved base allowed such blocks to lie thwartwise in the bottom of a boat, whilst the double arms enabled them to be slung by ropes on each side of a pack horse.

Among the chief localities which afforded tin from the earliest times and for many succeeding centuries, Cornwall occupies an important position. From thence the metal found its way by barter from tribe to tribe to Central and Southern Europe. It has been and is still held by some that the Phoenicians not only sailed to this tin-bearing district of Britain, but actually established colonies there. For neither of these theories, for theories they only are, is there the slightest foundation in fact. If the Phoenicians were the distributors of tin from Britain in the Mediterranean region, the tin had first reached the South of Gaul overland and was only then accessible to them. Even in Roman times it was never sea-borne to the Mediterranean, except for the crossing of the channel, but followed the old trade route, along with pigs of British lead, one of which has been found at St. Valery-sur-Somme, and the other at Chalons-sur-Saône.

In addition to Cornwall, the north-west of Spain (the provinces of Orense and Pontevedra) was also an important tin-bearing district, and it was from these two regions that the ancient world derived their chief supplies of tin. Subsidiary to these were the districts of Salamanca, Cartagena, and Almeria in Spain and the provinces of Beira, Minho and Tras-os-montes in Portugal.

In Italy, near Campaglia Marittima, not far from the Tuscan coast, there are extensive excavations made by the Etruscans for the extraction of tin-stone, which occurred there in irregular pockets and fissures.

Another mine on the east of the Monte Fumacchio was also worked by them.

Tin ores also occur on a minor scale in several other parts of Europe and doubtless afforded the men of the Bronze Age small quantities of the metal.

Of these localities I may first mention Brittany, where the tin veins of Cornwall are fully represented, and there are remains of ancient workings at Pyriæ near the mouth of the Loire, and at Villeder (Dept. Morbihan).

In the Erzgebirge there are also deposits of tin-stone, that appear to have been worked only in comparatively recent times, but as the ore occurs on the crests of the mountains, not only in veins but as surface deposits, it is not unreasonable to suppose that it was a source of tin in a much earlier age.

In Ireland tin ore undoubtedly occurs in the gravels of the streams in Wicklow, and has been found, but only in very small quantities, in washing the alluvium for gold. It is hence just possible that during the Later Bronze Age the locality may have been a source of tin.

Passing out of Europe to Asia we have in the Malay Peninsula and the adjoining islands of Banka and Billeton the most abundant occurrence of tin-stone in the world.

So far distant is it, however, from Europe and the lands of the great nations of antiquity that it is rather difficult to say whether or not that region was a source of tin in remote times. If it was, the tin may have found its way through India, but of this, we have, at present, no conclusive evidence.

In Persia we are on safer ground, in Khorasan Van Baer has discovered very ancient mines of tin ore, the metal from which could easily have been transported to Mesopotamia, Egypt, the Troad, and the Mediterranean.

In China, in Yunnan, tin-stone occurs in abundance in the old river gravels not far from deposits of copper ores and native copper and has been worked from the earliest times. The metal appears to have been known and used by the Chinese as a constituent of bronze from a very remote antiquity, probably as early as 3000 B.C.

At the beginning of the Hsia dynasty (2205 B.C.) it is recorded that the Emperor Yu cast the famous nine bronze tripod cauldrons from metal sent up from the nine provinces, which were preserved as palladia of the empire until about the third century B.C.

In Nigeria very extensive deposits of extremely pure tin-stone occur in the river sands or gravels, the district, however, is a remote one and was hence probably not accessible to the Mediterranean people.

Gold.

As I have already pointed out, gold, on account of its very wide distribution in the sands and gravels of rivers, its colour and brilliant lustre, must have been the first metal to attract and be known to prehistoric man in most regions of the world.

But its usual occurrence in grains or flakes, but rarely in small or large lumps as nuggets, must have prevented its use generally even for ornaments until the art of melting had been invented, and this can hardly have happened until man had passed beyond the Stone Age culture and entered the Bronze Age.

Yet in this connection it must be remembered that even in later times gold was not cast directly in the form of the object it was desired to make but merely in small masses or bars, which were subsequently fashioned by simple hammering.

So that the working of gold when found in lumps is perfectly compatible with the simple arts of the Stone Age and could have preceded the Age of Bronze.

Yet there has not been found, to my knowledge, any object of gold with undoubted Stone Age remains.

As is well known, gold from alluvial deposits, and these were undoubtedly the first deposits to be worked, contains more or less silver. If much is present the metal is very pale in colour; it was then termed *asem* by the Egyptians and *electrum* by the Greeks.

The art of separating the silver from it was not known in the earliest times. Agatharchides, however (about 113 B.C.), in his description of the Nubian mines mentions salt, lead, and bran as having been added to the gold before melting. These additions would certainly have the effect of removing the silver and purifying the gold, but only if followed by cupellation, which must have been practised for the removal of the lead, although he does not mention this.

From a knowledge of these facts, Berthelot inferred that from the presence or absence of silver the approximate age of an object of gold could be determined: the oldest specimens would contain silver whilst more modern ones would not. With the object of testing this view he made the following analysis:—

Gold.	Silver.	Organic matter.	Gold leaf from mummies of VIth Dynasty ...	Berthelot.
92·3	3·2	4·5	,, ,, ,, ,, ,, ,, ...	,,
92·2	3·9	3·9	,, ,, ,, ,, ,, ,, ...	,,
90·5	4·5	0·5	,, ,, ,, ,, XIIth ,, ...	,,
99·8	—	—	,, ,, ,, ,, Persian Era ...	,,

When, however, we consider that alluvial gold sometimes contains only small amounts of silver such, in fact, as might remain in gold treated by the old rude methods of refining, it is open to doubt whether his inference is applicable in all or even in any cases.

The specimens of the Persian era (527 to about 420 B.C.) in the above table is exceptionally pure and had most probably been treated for the separation of silver by the sodium chloride process which was then known.

It may, however, have been vein gold, as subterranean mining must then have been practised, and such gold has been found to contain 99·8, 99·9 per cent. of gold.

Under the term "electrum" are included various pale yellow alloys of gold and silver, natural and artificial.

It is often stated that the native alloy of gold and silver contains from 75 to 80 per cent. of gold, but this is pure theory, based solely on the statement of classical writers, Pliny and Isidorus, as it must have been much more variable in composition.

In a series of determinations of the specific gravity of electrum coins, a method which, however, only gives very approximate results, Barclay and Head found that in electrum coins varying in colour from rich yellow to yellow, the specific gravity indicated a range of from 36 to 72 per cent. gold and in others only pale yellow, and a very pale yellow, 10 to 43 per cent.

Now the colour of gold is rapidly lowered by only small amounts of silver, with from 20 to 40 per cent. of silver the colour changes by tints of greenish yellow to white, whilst with 50 per cent. silver the colour is absolutely white.

Hence the coins containing 50 per cent. and less of gold consisted of a perfectly white alloy, and any yellow colour they had was due to artificial colouring, probably similar to that practised by the Japanese, who, by treating gold and silver alloys with the juice of unripe plums, dissolve out the silver from the surface leaving a layer of yellow gold.

It is also almost certain that the alloys containing less than 60 per cent. of gold were artificially prepared, as no native gold of lower fineness has been found in any part of the world.

Electrum was apparently much prized, as it is mentioned so frequently along with gold. Yet the reason for this is not obvious, it may, however, have been

because the alloy is capable of receiving a more brilliant polish than silver, and is not liable to tarnish, or because when treated with an appropriate reagent, as the vinegar obtained from plum juice, the rich yellow colour produced was preferred to that of ordinary gold. Hence probably its use by the goldsmith for ornamental objects. In the coins of electrum, in which the proportion of silver is nearly always high and sometimes largely exceeds the gold, the alloy is undoubtedly artificial, the silver having been added to economize gold. A perfectly parallel case is found in Japan where the gold coins of certain issues contain only from 30 to 60 per cent. of gold; but from the colour resulting from the above treatment cannot be distinguished from those containing a higher percentage of the metal.

For a knowledge of the earliest mining and metallurgy of gold we naturally turn to Egypt and its confines, a region renowned as early as 1500 B.C. as a land in which "gold is as common as dust."

Whilst according to the stele of Sa Hathor, who lived during the reign of Amenemhat II. (2400 B.C.), the washing of the alluvial deposits in the Sudan was then a flourishing industry.

In this connection it is noteworthy that we owe to Egypt the first mining map in the world. It represents a mining district of the time of Seti I. (about 1350 B.C.), or Rameses II. (about 1330 B.C.), the locus of which has not yet been determined. It is depicted on a papyrus in the collection in Turin, which has been described by Chabas. A reduced copy is shown in Fig. 3.[1]

I and II.—Two parallel valleys, one of which is apparently strewn with blocks of stone.

The inscriptions on the papyrus describe some of the details of the map as follows:—

III.—Road to the sea—

A. Mountains where the gold is washed. (Another reading is "Mountains from which the gold is brought.")

B. Gold-bearing mountains.

H. Houses for the storage of the gold.

S. A stele of Seti I.

The large building on the side of the upper valley is a temple of Ammon and at T is a pond or tank.

The ancient mines are scattered over Upper Egypt, Nubia, and the Sudan. This gold-bearing region and the remains left by the old miners have been explored and examined during recent years by the engineers of the mining companies, which have been formed for exploiting and reopening the old mines.

The remains make perfectly clear to us the entire procedure of the ancient gold miners, from the breaking down of the gold-bearing rock to the production of bars of the precious metal.

[1] Reproduced from *Geschichte der Bergbau- una Hütten-technik*, Fr. Fricae, p. 11, by permission of Herr Julius Springer.

To what even approximate date the earliest of these remains should be referred is for the present a matter of conjecture, but the exquisitely wrought gold bracelet found by Petrie on the arm of the queen of King Zer, successor of Menes, takes us back to about 6,000 years ago, whilst a small ingot of gold found by Quiball in a prehistoric grave at El-Kab demands an even more remote date.

The ancient workings extend from lat. 27°, *i.e.*, north of Keneh, to lat. 18° a little south of Suakin and on the west to the Nile, a vast area of about 250,000 square miles.

It has been thought that this district in early times was extraordinarily rich in gold, from the almost fabulous amounts of the metal said to have been produced in it. It may possibly have been so, but in this connection it must not be forgotten

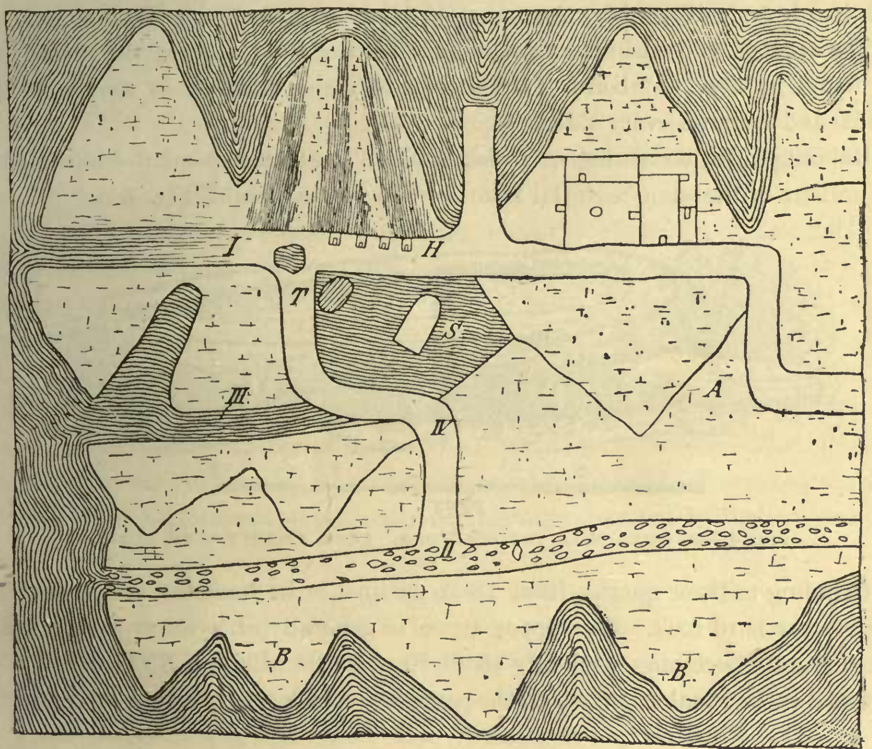

FIG. 3.—ANCIENT EGYPTIAN MAP OF GOLD MINE.

that skilful native gold washers in Yezo and elsewhere often recover gold with only a simple dish from sands which are too poor for treatment with our modern appliances. Further the "tailings," *i.e.*, the residue from which the gold has been extracted, which occur in large quantities at Um Gariart and elsewhere, are reported as containing only traces of gold. This tends to show how skilful were the old miners, and that if a sufficient amount of forced labour was available, vast quantities of gold may have been obtained from ores comparatively poor or of only ordinary richness.

Before proceeding to consider the appliances and methods of the old miners, as illustrated by the remains they have left to us, it may be well to state the

principle on which the simplest operations for the extraction of gold from sands and rocks at all times, even our own, depend. It is as follows:—When material bearing free gold, as sand, or rock which has been reduced to fine particles by grinding, is washed with water either in shallow dishes or on a sloping surface, the particles of sand or rock being lighter than the gold are washed away and the gold remains behind and can be collected.

The ancient mines consist of shallow pits in detritus, shallow trenches along the line of a vein, and subterranean workings, the first being probably the oldest. In the last mentioned, a number of shafts, sometimes 160 feet in depth, have been found sunk along the vein, where it appears at the surface, and connected by tunnels. Both trenches and shafts are often in very hard rocks, the mining of which had been facilitated by the action of fire as previously described.

The appliances used in the treatment of the ore after leaving the mines have been found in large numbers. They consist of stone hammers or mauls, roughly cuboidal and worn on every side.

Rubbing mills, consisting of a flat boulder or thick slab of the hardest rock with mullers of the same material from 5 to 15 lbs. in weight, Fig. 4.

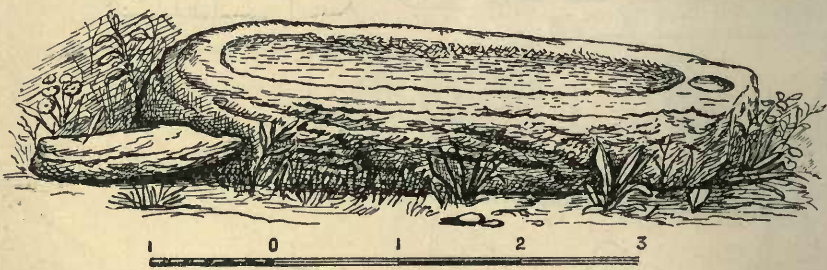

FIG. 4.—RUBBING MILL FOR GOLD ORE. FROM ANCIENT MINE, NUBIA.

Grinding mills or querns, from 18 to 20 inches in diameter, the nether stone being of very hard rock. The upper stone is generally of a softer rock, a coarse-grained granite, weighing originally about 50 or 60 lbs., Plate XXVII, Fig. 2.

Stone inclined tables, on which the particles of rock were washed away from the gold.

Broad flat dishes. The broken remains of these are common. They were used in the final washings.

Broken crucibles for melting the gold.

From the above-mentioned remains it is clear that the following procedure was carried out for the extraction of the gold.

The lumps of ore from the mines, after the rejection of the non-auriferous pieces, were broken up coarsely by the stone mauls either on a hard stone or on the rock *in situ*, the latter being in many places worn into holes by the operations.

The coarse ore was then taken to the rubbing mills, where it was reduced to finer particles, but not sufficiently fine for washing. It was therefore further

ground to a finer state of division in the querns, into which it was fed through a hole in the upper stone; after which it was ready for the tables.

The fine material was placed on the smooth inclined surface of the table and washed gently with water in such a manner that the light particles of stone flowed over the bottom of the table, whilst the gold remained upon it. Usually this gold would not be sufficiently freed from rocky or mineral matter for melting, this was then removed by a further washing in the shallow earthen dishes. The gold was now melted in crucibles and cast into ingots. From the quantities of slag found, fluxes of some kind must have been used with the intention of purifying the gold. Unfortunately, no analyses of the slags have yet been made, so that it is impossible to say what the fluxes were. The melting was, however, very carefully carried out, as no trace of gold can be detected in the slags by panning. Such were the appliances and processes of the prehistoric and protohistoric miners of this auriferous region.

From the above account it will be seen that the evidence afforded by the remains confirms in a very remarkable degree the description of the work of the mines given by Agatharchides.

In Japan, until quite recent times, the ancient method of grinding gold ores in querns before washing still survived, Plate XXVIII, Fig. 2.[1] In fact, the process in vogue was closely similar to that of the old Sudan miners, except that the coarse ore was first reduced to small size by iron pounders. The fine mud from the quern was washed with the addition of water on inclined tables, on which sheets of cotton cloth were spread. The particles of gold were caught on the rough surface of the cloth, and the earthy material was carried away by the water. The cloths were washed from time to time in cisterns of water when the gold and some earthy matter settled to the bottom and were finally completely separated by further washing in shallow dishes.

The ancient process for separating silver from gold by means of common salt I also found in use in Japan in 1872. The operations as conducted there throw considerable light on the mode of procedure followed at the early Egyptian mines, a somewhat confused description of which is given by Agatharchides. The gold from the final washing was mixed with common salt (sodium chloride) and clay, and piled up in the form of a cone in a broad shallow crucible. The whole was then introduced into a furnace containing charcoal as fuel and kept at a red heat for 12 hours, by which means any silver contained in the gold was converted into chloride. The dish with its contents was then removed, washed with hot brine and water, the silver chloride was dissolved and the gold left in a purified state.

We will now consider the chief sources of gold which were available to the peoples of antiquity.

In Europe itself there were few auriferous deposits, except in Macedonia, Thrace, Spain, Gaul, Dacia, Dalmatia, and Ireland.

In Macedonia, extensive remains of ancient workings are found near the source

[1] *Archaeologia*, vol. lvi, p. 272. Reproduced by permission of the Society of Antiquaries.

of the Gallico, a small river rising in a group of mountains to the north of Salonica. Within these mountains recent explorations have shown that every stream shows the presence of gold, and signs of ancient alluvial mining are very numerous.

The gravels are still washed in a desultory way after floods.

Tradition assigns the mines of Philip of Macedon to this region.

In Thrace, in the basins of the Strymon and the Maritza (the ancient Hebros), and in the Rhodope mountains, are considerable remains of ancient gold washings, and a little gold is still obtained in these districts, but to what extent they were productive in early times it is impossible to speak with certainty.

The evidence afforded by the remains would, however, tend to show that Greece was never very rich in gold.

In Spain, Phoenicians, Carthagenians, and after them, the Romans, found an almost inexhaustible richness in the noble as well as in the common metals. In widely-separated districts enormous heaps of waste and astounding underground workings testify to the magnitude of the mining operations, more especially those of Roman times.

Asturias, Galicia, the basin of the Sil, the north-western portion of the province of Leon, and the upper waters of the Ebro were the chief seats of Roman gold mining. Both alluvial deposits and quartz veins were worked. The skill and indomitable energy exhibited in the execution of this work is well shown by the remains left at the mine of Las Medulas on the boundary line of the provinces of Leon and Orense. Here, for the mere purpose of bringing water to the mines for washing the ore, there are seven ditches arranged one above the other, cut in the slate, each ditch being 26 miles long and 4 to 5 feet wide. The same men who planned these works turned the course of the River Sil at a point lower down, in order to wash the sands and gravel of its bed for gold. This was done by cutting through a promontory of solid rock a tunnel wide enough for the egress of the waters, and high enough for a sailing boat with main sail up to pass through it.

Other mines were worked in the south near Cordova, the Sierra Nevada, and other places, and in Portugal on the Tagus and Douro.

In Gaul, according to Diodorus, gold was so plentiful that both men and women were adorned with massive gold ornaments, but the objects which have been unearthed lend no support to this statement. Remains of ancient gold mines, however, occur on the northern slopes of the Pyrenees in the Cevennes and, recently, some remarkable excavations have been found in Limousin and Creuse and near Montrevault (Maine-et-Loire).

In Bohemia, an important ancient gold mine, said to have been worked in pre-Roman and Roman times is situated at Eule, 10 miles south of Prague, in the vicinity of, if not quite on, one of the main trade routes for amber from the Baltic to the Adriatic.

By " trade " routes, I do not mean that amber was actually carried by the men who found it, on the shores of the Baltic to the Mediterranean, but that they were the routes along which it passed by inter-tribal barter.

In Transylvania (Dacia), in the Cris (Körös) valley, an ancient gold industry was already flourishing in the time of Trajan, and some of the mines are even now worked near Vöröspatek and also at Zalatna.

In Bosnia (Dalmatia) there are also considerable remains of Roman gold mining.

Of the Urals there are no records by classical writers, but gold mining on a more extensive scale than elsewhere in Europe has been carried on from early times, and the mines there doubtless furnished the metal for the gold objects which have been dug up in the south of Russia.

Ireland.—In no country in Europe has a greater number or greater variety of gold objects been found than in Ireland.

The source of the gold has been variously ascribed to India, Gaul, Africa, and other countries. But gold occurs in six or seven localities in Ireland, notably in Wicklow. Hence there is no good reason for supposing that the gold of the objects was obtained from anywhere except the country itself.

In 1795, and for some years subsequently, the gravels of Wicklow, especially those of the streams from the granite mountain Croghan Kinchella, were worked by the Government and private people and yielded considerable amounts of gold.

Pieces of gold, according to Kinahan, have been dug up from time to time in the valley of the Dodder, and a nugget weighing $21\frac{1}{2}$ ounces was found in a stream flowing from the mountains mentioned above.

It is just possible, therefore, that the earliest gold ornaments of Ireland were made by the simple hammering of nuggets without melting and some may perhaps belong to the Stone Age.

In Britain, small nuggets have been found in Cornwall, but there have been no systematic workings there; in Wales, however, at Dolaucothy, near Pumpsant Carmarthenshire, there are extraordinarily vast remains of Roman mining. The auriferous veins extend chiefly across a width of 80 feet and have been mined both by open and underground workings. The waste heaps from the crushing of the gold-bearing rock are estimated to contain 500,000 tons of material, the mine must therefore have yielded a large amount of gold.

The regions of Asia, noted by the poets, historians, and geographers of antiquity, have been but little explored by geologists or miners, so that we are only imperfectly acquainted with the extent and nature of their ancient workings. The sands of the Pactolus, formerly proverbial for their richness, still yield gold to infrequent and indigent washers, and the streams of ancient Colchis have not ceased to bring down the precious metal from the regions of Armenia and the Caucasus, yet only in irregular and scanty amounts.

But it was not from these regions only that Asia supplied the ancient world with gold. In the upper basin of the Amu Daria, and its tributaries, in the Bokhara district, and in the lower slopes and streams of the Altai Mountains, extensive heaps of the mining refuse testify to the large quantities of the metal which must have been procured there by the miners of early times.

China is not rich in gold and the auriferous sands of the rivers of Korea were not worked at a very early period.

Further north, however, in the Manchurian region and Siberia, the basins of the Amur, Sungari, Tumen and Lena Rivers have yielded in the past and are now yielding very large amounts of gold, but, unfortunately, there is no evidence to show to what extent, if at all, they were exploited in prehistoric or protohistoric times.

India, at all times, has been regarded as a land of gold, yet the gold-bearing districts are almost exclusively confined to comparatively small areas in the south, so that the question naturally suggests itself, whether the gold was chiefly obtained by mining or by external intercourse.

Gold certainly occurs in small quantities in the sands and gravels of many rivers and streams, but the chief remains of ancient workings are found in the Wynaad district of Malabar and Nilgiri, and in Mysore and Haiderabad. In the former the country is covered with detritus left by the ancient miners, who here were not content to treat only the alluvial deposits but sank shafts in the quartz veins, yet none of the large number of mining companies with modern equipment has been able to extract the gold of this field with profit.

In Mysore, where the goldfield has become an important one, very extensive ancient workings occur, in some of which the shafts extend to a depth of 300 feet.

In the state of Jashpur (Central India) there are tracts of alluvium in the valleys honeycombed with shallow pits of the old gold miners, but the deposits are extremely poor. The streams of the Punjaub contain but little gold.

As regards Persia, its golden mountains can only be regarded as poetic fictions.

On a review of the above facts as regards the gold production of Asia, it would seem to be in the highest degree probable, if not absolutely certain, that the chief localities in this continent from which the nations of antiquity derived their gold were Lydia, Colchis, Bokhara, and the Altai region.

The last-named region may be thought to be too remote, but we must remember that the jade found by Schliemann in the first, second, third, and fifth cities must have been brought from the equally distant Kuenlun Mountains, the only locality in which this stone is found.

We have now considered the chief localities of the ancient world in which gold-bearing gravels or rocks have been worked in early times, the interesting question now arises—from whence did each of the various peoples and nations of antiquity obtain their gold?

In relation to this it is almost unnecessary to point out that for the acquirement of valuable objects or materials, distance does not appear to have been an insuperable obstacle even in very remote times, thus in Europe we find amber following regular trade routes from the Baltic to the Mediterranean before the dawn of history, and in Asia, as we have already seen, jade finding its way from the Kuenlun Mountains to Hissarlik.

As regards the source whence the ancient Egyptians derived their gold, the answer presents no difficulties, as the rich auriferous regions of Upper Egypt were

at their very doors, and both records and remains testify to the vastness of their mining operations, and the vigour with which they were carried on.

On the opposite shores of the Red Sea the land of Midian has been claimed as an important source of gold to the ancient world, and especially to the Egyptians, the country, however, has not been examined by mining experts, it is hence impossible to say whether or not there is any foundation for such a claim.

Assyria and Chaldaea, so far as archaeological investigations have gone, have yielded but little gold either as funeral ornaments or domestic or ceremonial vessels or appliances; on the other hand, their records speak of extraordinarily vast, almost fabulous, amounts received as tribute or obtained as the spoils of conquest. And indeed, these, although much exaggerated, must have been to a great extent the principal source of the metal. There are no auriferous deposits in Mesopotamia, and it has been supposed that Babylon obtained much gold from India, but there is no satisfactory evidence to show that that country was an exporter of gold.

That it was imported from Egypt during the XVIIIth dynasty we have the testimony of the Tell-el-Amarna tablet No. 8, in which Tushratta, writing to Amenophis III. (about 1450 B.C.), says: "Send me so much gold that it cannot be measured, more gold than thou didst send to my father; for in my brother's land (*i.e.*, Egypt) gold is as common as dust."

The Minoans, if we may so call the people of the ancient empire of Knossos, for whose beginning we have to go back as far as 4000 B.C., next call for our attention. As has been shown by the brilliant discoveries of Sir Arthur Evans they were a trading people whose empire rested on sea-power, so that for the gold they needed we are not limited to one region only.

One of the chief sources must have been the rich Nubian mines, the gold from which would reach them through Egypt, or more probably through Libya, where there were one or more Minoan settlements, and with which country there was an established intercommunication.

The auriferous region of Mount Tmolus in Lydia, and possibly the gold-bearing gravels of Macedonia and Thrace, may also have contributed to their wealth in gold.

The Mycenaeans, who were also possessed of much gold and were, too, a seafaring people, doubtless obtained the metal from the same sources as the Minoans.

A wider range in auriferous localities was possible to the later peoples of Greece. Colchis and the Amu Daria region, certainly, and probably the remoter parts of Asia—the districts of Yakutsk and the Amur—contributed to their wealth in gold. But not inconsiderable quantities must have been obtained from Egypt, Gaul and Spain, and from even their own mines in Siphnos, Macedonia, and Thrace, whilst the spoils of conquest in Asia afforded an amount of the precious metals which it is impossible for us to estimate.

The Romans after establishing their supremacy in both the west and the east

were in possession of all the auriferous districts of Europe and Western Asia and possibly of those of Upper Egypt and Nubia.

The richest mines were those of Galicia and North-west Leon (Spain), Vöröspatek, Transylvania, Bohemia, and Bosnia, in all cases mines which had already been worked by the inhabitants of these districts.

I have already described the magnitude of the Roman works at Las Medulas (Spain) and Dolaucothy (Wales), but in other parts of Spain and at Vöröspatek (Alburnus Major), Transylvania, the mining operations were conducted on a not less magnificent scale.

At the latter place Mr. Horace Sandars, who visited it in 1903, states that a trachyte mountain has been literally hollowed out from the top, and in most places by the aid of fire.

I am also indebted to him for the illustration of the bas-relief found near Palazuelos, representing Roman miners in Spain. Plate XXIX.

His description of it is as follows: "The bas-relief represents a gang of stalwart men going leisurely to their work. The foreman, being a person of much importance, is a big man. He carries in his right hand a pair of large double-looped tongs, while his left hand is passed through the ring of some hollow object, which may be a bell. The miner who precedes him carries, in a somewhat unnatural position, a pick, or rather an implement which served either as a hammer or a pick. The miner in front of him again carries a lamp. Whether the other two in the front row carried anything or not it is impossible to say. The men are represented as moving along, and that they are walking through a gallery is, I think, shown by the striations in front of the foremost man. Each man has the middle part of the body protected, apparently, by short drawers, while over them there is what appears to be a leather band or belt, probably a very useful protection against friction and bruising by the baskets in which they carried the rock and ore to different parts of the mine. The appearance of the eyes is due to the long exposure of the stone to the elements."[1]

Silver.

The metal silver is, like gold, found in the native state, *i.e.*, as pure metal, but in that form it has only a very limited distribution and usually occurs in but very small quantities.

Alluvial deposits, or the sands and gravels of rivers, do not contain it, and it has to be sought for in mountain regions, where it is embedded in mineral veins. It differs, too, from gold when it occurs in the native state in being almost invariably in the forms of delicate filaments or thin foil, and very rarely in lumps or nuggets, so that, without being first melted, it could not be made into even the simplest objects. Hence, it has played no part in the culture of early man, and, indeed, it has never been found in association with any of his remains until long

[1] *Archaeologia*, vol. lix, p. 321. Reproduced by permission of the Society of Antiquaries.

subsequent to the time when he had become acquainted both with gold and copper.

The ores from which the metal was first obtained were undoubtedly either ordinary lead ores, in which it is invariably present, or silver ores containing considerable amounts of lead.

In the absence of lead, the silver could not be extracted by any process until comparatively recent times; and although there is evidence that the Romans were acquainted with true silver ores, yet in order to obtain the silver they contained they were compelled to mix them with lead ores before smelting.

The first and essential process then for the extraction of silver was the process of smelting ores for lead, the product being always the latter metal containing the former dissolved in it in greater or less proportions.

Therefore it follows that the metal lead must have been known to man at least a short time before he became acquainted with silver.

The chief ore of lead, galena, which always contains silver, is of very common occurrence, and in many localities is found in vast, almost inexhaustible, deposits, which, as the remains of ancient excavations show, once cropped out at the surface of the ground.

The ore, too, is of brilliant metallic appearance and of high specific gravity. Characters which cannot have failed to excite the curiosity of primitive man. Its great brittleness, however, would render it worthless to him for any practical use, but if, as the late Dr. Percy[1] has remarked, "he were to throw it on his blazing wood fire, even he could hardly fail to observe the remarkable change it might thereby undergo. The hard brittle ore might in a greater or less degree be transformed, as though by magic, into soft malleable lead." I think there can be no doubt that the discovery of the metal arose in this way and that the first silver-lead smelting furnace was the domestic fire.

The discovery of the metal silver by early man must have very closely followed, if indeed it was not simultaneous with the discovery of lead, for, if by chance a piece of lead was left in the camp fire for some time, the lead would be entirely dissipated owing to oxidation and volatilization and a small piece of silver would be left.

Of course the discovery of the metal in the native state may perhaps have come first, but on account of its form, as we have seen, it could not be utilized, hence it is only with the discovery of lead that the history of silver really begins.

The methods by which lead and silver were obtained in early times from argentiferous lead ores or silver ores mixed with lead ores, and these were the only available sources of silver, will now be briefly considered. For the elucidation of these methods and the appliances employed we are aided not only by a study of those in use in Japan, which have survived there from prehistoric times, but also

[1] *The Metallurgy of Lead*, by Dr. Percy, p. 213.

by the actual remains which have been unearthed at Laurion in Greece, in Spain,[1] and at Silchester in our own country.

With these data as a basis we are led irresistibly to the conclusion that the earliest furnace was simply a shallow circular cavity in the ground which in somewhat later times was enclosed within a low wall of stones. Of the latter kind were the furnaces in use at Laurion, where the extensive deposits of argentiferous lead ore had been worked many centuries before Roman times.

The same type of furnace was also in use in Derbyshire, where these rude hearths were employed until the seventeenth century.

Of the Derbyshire lead smelters of that date it is recorded that "They melt the lead upon the top of the hills that lye open to the west: making their fires to melt it as soon as the west wind begins to blow, which wind by experience they find holds longest of all others."

No artificial blast was used and a more simple metallurgical operation cannot be conceived. At Laurion and in Spain, however, the blast pipes which have been found would show that in some cases at least some form of blowing apparatus had been employed. The ore was smelted in these furnaces in a precisely similar manner to that already described under copper (page 241). The metal produced consisted of lead containing nearly the whole of the silver present in the ore, and it was necessary to extract the silver from it. This was effected by the process of cupellation.

The manner in which this operation was conducted by the Romans and by the Greeks is clearly shown by the remains of a silver refinery, and the products of the process discovered in Silchester, which I examined a few years ago and by others found in Spain, Gaul, Laurion and Siphnos. The furnace or hearth was of exactly the same character as the primitive cupellation hearth of Japan, except that its upper layers consisted of bone-ash (calcined bones ground to powder) instead of wood-ashes and it was undoubtedly worked in the same way. It is worthy of note here that bone-ash is still employed in modern furnaces although it is gradually being replaced by other materials. The furnace consisted simply of a shallow cavity in a layer of bone-ash partially enclosed by stone or clay slabs in such a manner that a small chamber was formed around and above it. A charcoal fire was made in the chamber and the lead to be desilverized was placed on it and melted. When sufficient had accumulated in the furnace cavity the fire was raked off towards the sides, a blast of air was then introduced, by which the lead was oxidized, the lead oxide formed being absorbed by the bone-ash and a cake of silver, which also contained any gold that had been present in the ores, was left in the cavity. The

[1] Pliny's account of the treatment of argentiferous lead at the mines in Spain is extremely obscure. A strict interpretation of the passage would ascribe to silver a property which it does not possess, namely that of floating on lead as oil on water. If, however, it is permissible to suppose that the words *plumbum* and *argentum* have been transposed in copying the old manuscripts, and if *plumbum* may be taken to mean the product of the oxidation of *plumbum nigrum*, then the obscurity disappears and the elements of an outline sketch of the process are clearly presented. *Nat. Hist.*, xxxiii, p. 31.

silver resulting from the process when the lead ores were pure contained but small quantities of impurities and was regarded as pure by the Greeks and Romans as it is by the Chinese at the present day.

The silver from impure ores was sometimes impure from the presence of copper, etc., and was then again cupelled with pure lead in another but similar furnace.

The Japanese were especially skilful in conducting these processes, Plate XXVIII, Fig. 1,[1] and seem to have had no difficulty in producing silver of considerable purity by their means.

I have assayed the silver thus treated very often, and the most impure Japanese specimen I have ever found contained 97·5 per cent. and the purest 99·7 per cent. silver. Its average composition deduced from the assays of 555 samples was 99·0 per cent. silver. Even in very ancient times, during the period of the dolmen builders, the Japanese seem to have been skilled in the metallurgy of this metal, as the silver beads of that date contain but very small proportions of lead and copper.

That the Greeks and Romans were not less skilful in conducting this process is proved by the high percentage of silver contained in many of their issues of coins, for which this silver was undoubtedly employed.

Thus the tetradrachmas of Athens sometimes contain 98·3 per cent. silver, and the coins of the Romans, especially during the periods of the Republic and of the Empire up to the time of Nero, and again with a few exceptions from Constantine to Justinian, frequently contained 98 to 99 per cent. silver. When the percentage of silver falls to 97 per cent. it is the result of either careless work or of an intentional stoppage of the process before the refining is completed. Much lower percentages as 95·0 and below indicate the intentional addition of copper.

It has been asserted by a Continental author that the production of silver by the cupellation of lead was unknown in Mycenaean times. But this assertion is based on imperfect data, in the absence of a quantitative chemical analysis, and on a superficial acquaintance with metallurgy. He states that the silver from Mycenae was very impure because, besides gold, it contained copper and antimony. Now gold and copper are universally present in cupelled silver, antimony is by no means uncommon in very small quantities. That antimony was not present in larger proportions than are found in cupelled silver is proved by the forms and workmanship of the Mycenaean cups and vases. A very small quantity of antimony renders silver so exceedingly brittle that if it were present in more than traces it would have been quite impossible to construct these vessels.

I append in the following table the analysis of:—

1. A silver bar from the "burnt" city at Hissarlik (Schliemann).
2. A silver vessel from Mycenae (Schliemann).
3. A Roman patera (British Museum).

[1] *Archaeologia*, vol. lvii, p. 120. Reproduced by permission of the Society of Antiquaries.

No.	Silver.	Copper.	Gold.	Iron.	Lead.	Nickel.	Analyst.
1	95·61	3·41	0·17	0·38	0·22	—	Roberts-Austen.
2	95·59	3·23	0·30	0·12	0·44	—	Percy.
3	95·15	3·44	0·47	0·07	0·33	—	Gowland.

Now Roman silver was undoubtedly obtained from argentiferous lead by cupellation, and as the specimens from Mycenae and Hissarlik are practically identical in composition with it, the silver of which they consist must have been obtained by the same process.

In this connection the assays of Roman silver objects in the British Museum, which I have been permitted to make through the courtesy of Sir Hercules Read, are of considerable interest.

They gave the following percentages of silver :—

Spoon, 95·64; dish, 94·30; dish, 92·50; rim of vessel, 95·52; bottom of another vessel, 94·90; patera, 95·15; large dish, 95·09.

In these assays the proportion of silver present ranges from 92·5 to 95·6 per cent., which would almost seem to indicate that this composition was aimed at by the Romans for what may be termed silver plate and was of the nature of a definite standard.

In the history of culture the discovery of silver and the application of the metal to useful purposes play a minor yet by no means an insignificant part. Less widely distributed than copper and more difficult to extract from its ores, wanting in the properties which made bronze so valuable for implements and weapons and in early times less abundant than even gold, it seems to have been but little used until a few centuries before Mycenæan times.

In North Europe silver was almost entirely unknown or at least unused in pre-Roman times, and even in South Europe it is of rare occurrence in the Bronze Age. In the pile dwellings of the European lakes it has not been found excepting in association with objects of the Iron Age, nor has its occurrence been noted in the *terra maræ* of the Po valley. Probably the earliest specimen is a pin, which was found in Central Italy and has been ascribed by Montelius to the first part of the Bronze Age, to which he gives the date 2100 to 1950 B.C.

The localities whence the ancient peoples of the Mediterranean region derived their silver were all within comparatively easy reach. The deposits of Macedonia, Thrace, Laurion, Siphnos, Sardinia, the south-east of the Euxine and the west of Asia Minor were all available to the Minoans and Mycenaeans, whilst in the times of Phoenician maritime enterprise and of Greek and Roman ascendancy, Spain especially, Gaul, Britain, Dalmatia, and numerous sites in Asia Minor all afforded more or less abundant suppplies of the metal. In Asia Minor the remains of old workings have been discovered in many places, notably in the back country to the south, south-west, and south-east of Trapesne (mod. Trebizonde), Northern

Armenia, Anatolia, and near Balia on the north-east of Mount Ida, and several have been reopened and are now worked by mining companies.

It is difficult to arrange in exact chronological sequence the ancient silver objects which the excavations and researches of archaeologists have revealed to us. Some of the earliest present such technical skill, not only in the purification of silver but also in its fabrication into elegant and graceful forms, that it would almost seem as if the very first examples of the use of the metal had not come down to us. It should, however, be remembered in relation to this, that long prior to the utilization of either of the precious metals, copper and bronze objects, perfect in workmanship and excellent in design, were not uncommon, and in the manufacture of these the metal workers had acquired great experience and skill in the fashioning and decoration of metals.

For the earliest use of silver there is much evidence to show that we must pass eastward out of Europe into Asia, but in which parts of Asia lay the original home of silver, whether in the east in China or in the west in Asia Minor, the data for arriving at an absolutely definite conclusion are insufficient.

The earliest use of the metal has been claimed for China, where as early as 2400 B.C. three metals are said to have been used as barter, the yellow, the white, and the red, namely, gold, silver, and copper.

It was without doubt known in that country in very remote times, but Chinese chronology, whilst possessing the quality of precision, lacks that of accuracy, so that it is quite impossible to assign an even approximate date to most of the records contained in the ancient books.

But it is almost certain that for the oldest objects of silver yet found we have to go to Western Asia, where some remarkable specimens of early work in silver have been unearthed by the excavations of Schliemann at Hassarlik, which, in fact, if the dates attributed to the strata in which they were found are correct, are the most ancient examples of wrought silver in the world.

They consist of a silver pin, an ear-ring and a piece of wire, which were found in the lowest city to which the date 3000 to 2500 B.C. has been ascribed by Tsountas and Manatt.

In a higher stratum, containing the remains of the Third City (2500 to 2000 B.C.), the prehistoric fortress of Dörpfeld, there was quite a wealth of silver vessels and objects, comprising eleven vases, goblets, jugs, etc., six silver bars, some personal ornaments as well as crucibles in which gold and silver had been melted.

Several of the vases and goblets are of graceful forms and delicate workmanship, indicating not only remarkable technical skill in the working of the silver, but also that the metal had been refined by the process of cupellation. That this process had been employed in the purification of the silver, which has been used for the silver bars, I have already shown on page 264.

As regards the Minoans, the comparative absence of silver objects at Knossos is difficult to understand, in view of the facts that they were specially distinguished as a sea-faring people, and must, therefore, have had communication with the silver-

bearing regions near the coast of the Aegean and of Asia Minor, and their vessels and utensils of bronze and their work in gold testify to their skill as artificers in metal. The only explanation that seems possible is that the city was not only destroyed by fire, but was plundered before its destruction. On the other hand, objects of the metal should have been found in the tombs.

Somewhat later in time, at Mycenae (about 1600 to 1200 B.C.), in addition to the wonderfully lavish employment of gold, we find silver also freely in use, chiefly for the fabrication of vessels, some of which are of imposing size, notably a silver vase found in the First Sepulchre, which is 2 feet 6 inches high and 1 foot 8 inches diameter at the body.

They are generally plain, and when ornamented with repoussé or other designs the artistic work is inferior and coarser than that executed in gold.

The famous cow's head with golden horns, found by Schliemann in the Fourth Sepulchre at Mycenae, a perfect specimen of artistic modelling, and one of the Vaphio cups form, however, exceptions to this rule.

An analysis of a portion of one of the vases from Mycenae was made in Dr. Percy's laboratory. The analysis is given in the table, page 266, where it will be seen that its composition is practically identical with that of one of the silver bars from Hissarlik, and that silver refined by cupellation had been used in its fabrication.

In a later age the Homeric poems testify to the importance of silver as a valuable metal for vessels of various kinds, and to its manifold applications to the ornamentation of furniture, chariots, weapons, etc.

Alybe, on the southern shores of the Euxine, is mentioned as the home of silver, from which it would appear that the famous argentiferous deposits of Laurion in Attica had not been discovered. Greece was then evidently dependent on Phoenician commerce for its supplies of silver and silver wares.

In Chaldaea there is quite an absence of silver in the early graves which have been explored at Warka and Mugheir, yet amongst the remains not only copper, bronze, and gold, but also lead and iron were found. As lead occurs, the absence of silver is the more remarkable. It is very difficult to account for this, in view of the comparative abundance of the metal at Hissarlik. The source which furnished the early inhabitants of the Troad with silver was probably the mining district to the south-east of Trebizonde and south-west of Asia Minor, and these were accessible to the Chaldaeans, and they must have been acquainted with the ore deposits of Armenia and Kurdistan, otherwise whence did they obtain their copper and iron ?

Moreover, the records of somewhat later times show that the metal was received as tribute, formed part of the spoils of war, and vast amounts had accumulated in Nineveh.

In Egypt there is a marked absence of silver objects in early times, which is difficult of explanation. Silver wire and silver rings of the XVIIIth dynasty, about 1600 to 1400 B.C., have indeed come down to us, but they are the only examples of the use of the metal in the country until a comparatively late date.

In the wrappings of mummies, gold ornaments were frequently employed whilst those of silver are rare.

As there are no silver mines in Egypt, the metal was probably first obtained from the refining of the electrum of the Nubian gold mines, and later from the deposits in Asia, or as spoils in war.

In the course of centuries, however, silver had accumulated to an extraordinary extent, if the accounts of the destruction of Thebes by Cambyses (526 B.C.) are only approximately true, when it is said that an almost fabulous amount of the metal, exceeding sixty tons in weight, was taken out of the rubbish.

It might be supposed that the paucity of discoveries of silver objects of very remote times might be due to the destructive action of the weather, or of salts in the soil, on the metal. This is, however, by no means true. The metal resists well the action of all corrosive agents, commonly present in the air, rain and soil, excepting chlorides. In rain chlorine as sodium chloride is always present, it is also present in the soil. Hence silver objects which have been long buried are always more or less converted into silver chloride. Sometimes they are wholly changed into this substance, but generally a small unaltered core of silver exists within them which enables them to retain their shape. Even when completely changed into silver chloride their form is more or less retained; silver chloride, however, although comparatively soft and sectile is a very indestructible substance, so that even these ought to be found.

Equally noteworthy with the peoples already mentioned are the Phoenicians, about whom much has been written, often in error, as our knowledge of them is very far from being so complete as might be desired, and there are good grounds for holding that much which has been attributed to them really belongs to the early Aegean peoples.

If the predominance of Sidon was reached in the tenth century B.C., and the supremacy of Mycenae came to an end in the twelfth century, the Phoenicians would seem to have been a great maritime people in late Mycenaean times and to have continued so for several centuries until the Greeks had wrested the sea power from them.

They were then the merchants and traders of the world and as such had become rich in silver, which they obtained from Spain, Gaul, Thrace, the silver-bearing districts in Asia Minor already mentioned, and probably Laurion, and which they distributed in the form of finely wrought bowls, cups and other objects of the metal through the Aegean and other regions of the Mediterranean.

Another ancient people, the Etruscans, are more noted for their bronze and iron than for their possessions of silver. Yet the excavations, which have been made on the ancient sites in Etruria and the explorations in the tombs tend to show that silver was in use to a considerable extent. Personal ornaments are rare, and the metal appears to have been chiefly used for bowls and vessels for domestic use, mounts for furniture and the like. In the famous Regulini Galassi

tomb (eighth or ninth century B.C.), whilst the objects of gold are numerous those of silver are but few.

There is no evidence of silver mining in their territory, hence the metal must have been obtained by commercial intercourse.

In Italy proper there are no deposits of silver-bearing ores, hence in the early days of Rome what little silver was required had to be obtained from without.

In later times, at the close of the First Punic War (241 B.C.), the valuable mines which had been exploited by the Phoenicians in Sardinia came into the possession of the Romans. About forty years later, as one of the results of the Second Punic War, the Phoenicians had to relinquish to them the mines of Spain, the most valuable in the ancient world.

From that time the wealth of the Romans in silver must have equalled if not exceeded that of the earlier nations of antiquity.

Lead.

The metal lead, although it must have been one of the first metals, if not the first to be obtained by the reduction of ores, on account of the low temperature required and its great fusibility, required but a brief notice, as being entirely wanting in the physical properties needed in weapons and implements and worthless as a constituent of bronze; it was wholly without influence on the culture of the Bronze and Iron Ages. In fact, it could be and was only utilized by the peoples of antiquity after they had made those great advances in civilization which characterize the Chaldaean, Assyrian, Egyptian, Greek, and Roman nations at the height of their supremacy.

As I have already pointed out the intimate connection existing between the metallurgy of lead and silver, and have described under the latter metal the smelting of lead ores, it is unnecessary to further consider the method of obtaining lead.

As to the time when the metal was first known to man, there is as yet no absolutely decisive evidence. So far as my investigations have gone, it has not been found amongst any remains which can with certainty be attributed to the earliest Metal Age in Europe. Neither does it occur as a constituent of the metal of any implement or other object of that time, excepting in comparatively small proportions.

But near the close of the Bronze and during the early part of the Iron Age, lead frequently appears in considerable proportions as a constituent of bronze, and when more than about 8 per cent is present it has undoubtedly, in nearly every case, been intentionally added.

The following analyses in illustration of this may be cited :—

	Copper.	Lead.	Tin.	Iron.	Analyst.
Sword (Ireland)	83·50	8·35	5·15	3·00	Davy.
Cauldron (Scotland) ...	84·08	8·53	7·19	0·03	G. Wilson.
Socketed celts (Brittany)...	—	28·5 to 32·5	Trace to 1·50	—	Paligot.

In these copper-lead-tin bronzes it will be seen that the percentages of lead present range from 8·35 to as much as 32·5. In consequence of this they are so deficient in hardness and toughness that they are unsuitable for weapons or implements. It is hence difficult to conjecture why the socketed celts should have the composition given, unless they may have been intended merely as appurtenances of sepulture and not as implements for actual use.

Objects of lead of the Bronze Age are but few in number. They consist only of unimportant articles, such as sinkers for nets and the like. Three socketed celts of the metal have indeed been found, but they must have been worthless for any practical purpose.

This is somewhat remarkable, as in many localities in Europe rich lead ores then cropped out at the surface of the ground; and it is hardly conceivable that the men who were able to smelt the difficult ores of copper should have either overlooked or been unable to treat the easier ores of lead.

None of the leaden remains which have been found are earlier in date than the palstave or the socketed celt in either Britain, France, or Spain.

The paucity and the trivial nature of these objects indicate clearly that the part played by lead in the culture of the time was of an insignificant character, and the metal was probably but little sought after.

If we now turn to Western Asia we find a remote antiquity has been established for lead, by the discoveries of Schliemann at Hissarlik.

In the Lowest City (3000 to 2500 B.C., Dörpfeld) the metal occurs in shapeless lumps. They are perhaps the most ancient specimens of lead in the world.

In the Third City (2500 to 2000 B.C.) a figurine, and in the Fourth City (2000 to 1500 B.C.) a diminutive wheel, both of lead, were unearthed.

The sources whence the people of the prehistoric towns at Hissarlik could obtain the metal were not far distant, in fact they lay at their very doors. In the mountain district to the north-east of Mount Ida, in Mysia, and at various points on the range of which Mount Olympus forms the prominent peak on the frontiers of Mysia and Bithynia, there are considerable deposits of argentiferous galena, and these it was which furnished the lead.

It may be mentioned in this connection that the sites of several of the ancient workings for ore in this district have been exploited in recent years, notably at Hodsha-Gernish (Balia) to the north-east of Mount Ida, and at Karie-Sennluk and near Broussa on the Olympus range, and have yielded both lead and silver.

For the culture of the primitive age represented by these remains it is evident that lead had but little importance, it is not, in fact, until the development of Mycenaean civilization had made considerable progress that it appears as a metal applied to useful purposes on a wider range.

It was still, however, but scantily used. Discs of lead similar to those at Hissarlik were discovered at Mycenae, in the Vaphio tomb, and in the beehive tomb of Thoricas, but at the island fort of Gha in Lake Copäis, in Boeotia, it was

found in the form of plaques, which are supposed to have been used for clamping door jambs to walls.

At Tiryns it was found in the citadel, to which the date 1800 to 1600 B.C. has been ascribed, and in many places. Of these discoveries Schliemann writes: "There were found numerous fragments of large vases and jars bound together with clamps of lead, as well as occasional lead clamps, which must have served the same purpose. We found, also, many large melted lumps of lead, as well as one large piece in the form of half a pig, and several fragments of sheet lead."

Specially worthy of note is a leaden statuette which was found by Dr. Tsountas in a beehive tomb in Laconia. It is a casting of remarkable merit, and as it probably exemplifies the "elementary costume of the Mycenaean people, it is also of great archaeological interest.

"Great leaden jars, as much as 3 feet high, used mainly for storing grain," are mentioned as being in use in the Mycenaean Age, but I have so far failed to find any record of the actual discovery of such vessels.

The rich deposits of argentiferous galena, which occur on an extensive scale in the region of Laurion in Attica, afforded the Mycenaean people ample supplies of both lead and silver. These deposits, in the earliest times, as is shown by the numerous superficial workings, were exposed at the surface of the ground, and I think there can be little doubt that the mines of Laurion, so famous in a later age, had been previously worked by them.

The discovery of three domed tombs, containing undoubted Mycenaean remains, at Thoricos, in the mining region of Laurion, in the vicinity of many primitive superficial mining excavations, affords very strong evidence indeed in favour of this view.

If we pass now to another region of ancient civilization, the country lying between and adjacent to the Rivers Euphrates and Tigris, the rarity of the discoveries of lead which have been made there further emphasizes the limited use to which the metal was put in early times.

In Babylonia there is no positively certain evidence, *i.e.*, evidence derived from actual discoveries, that lead was in extensive use. On the other hand it is recorded by Herodotus, who visited Babylon about the middle of the fifth century B.C., that a bridge built across the Euphrates by the Queen Nikotris had its stones bound together with iron and lead.

The metal, too, is said by Diodorus to have been largely employed in the construction of the famous hanging gardens of the capital city. Loftus obtained a jar of the metal and a fragment of a pipe at Mugheir (Chaldaea). It has also been taken from some of the oldest graves at Warka. No specimen, however, is to be found in the extensive collection of Chaldaean objects in the British Museum.

In Assyria the excavations which have been made from time to time on the site of the ancient capital and other cities have brought to light but few objects of lead. Layard mentions a mass of lead melted by the fire, which had destroyed the

temple in the ruins of which it was found. Yet the Chaldaeans and Assyrians were very favourably situated for obtaining the metal.

In the mountain region to the north-east of Nineveh and not very far distant, in the neighbourhood of Lizan, and in the valley of the Birwari there is an important mineral district, throughout which are distributed valuable deposits of lead ore.

The still richer districts of South Armenia, near the modern Diarbekhr on the upper waters of the Tigris, were also by no means inaccessible to them.

As regards Egypt, no deposits of the ores of lead are known to occur within its borders, or in the regions on its frontiers, and it is probably for this reason that the metal was but very rarely used, even in comparatively late times. In fact, even as late as the Ptolemaic period it was employed by the Egyptians to a much lesser extent than by the Mycenaean people, and its applications were confined to very trivial uses.

As a constituent of bronze it seems to have been much in favour, thus in twenty-two analyses of Egyptian bronzes, chiefly statuettes, published by von Bibra, fifteen show from 7 to 22 per cent. of lead.

The earliest example of the use of lead as metal is a hawk of wood coated with lead, which was found by Petrie in a grave at Nagada, along with three similar archaic figurines of limestone.

If this is contemporaneous with the early objects found on that site, to which the date 3300 to 3000 B.C. has been ascribed by Petrie, it rivals the Hissarlik specimens in its remote antiquity.

The Phoenicians claim our attention as the discoverers and first exploiters of the lead and silver-bearing deposits in Sardinia and Spain, and possibly those of the Taurus and some others on the western and northern coasts of Asia Minor, and in the valley of the Nestus, in Macedonia. According to the statements of classical authors they were especially noted for the abundance of silver, which they possessed, but, as I have already pointed out (page 263), silver can only be obtained by smelting ores containing lead, they must, therefore, have been well acquainted with that metal. None of the sites of these ancient cities or settlements have, however, yielded any evidence of the use of lead, excepting for minor purposes.

We have already noted how lead was applied to various industrial purposes in Mycenaean times.

If we now pass in review its applications during the later period of Greek culture, from the beginning of the Hellenic supremacy in the Aegean up to its fall at the hands of the Romans, we shall see that they were still but little extended and for the most part of but minor importance.

In architecture, lead was employed in the form of dowels for fastening firmly together the larger stones of important edifices, also for affixing to them the bronzes with which they were occasionally adorned. Examples of both are seen in the debris of the Mausoleum, at Halicarnassus.

For civil and religious purposes we find inscribed tablets, plaques, and figurines for votive offerings.

For the needs of common industries there were weights, plummets, and the like, and for the purposes of warfare, sling bullets of lead.

All these are, however, applications of minor importance, consuming but insignificant quantities of the metal.

The sources whence the metal was obtained were the mines of Laurion, the islands of the Aegean, and the west and north of Asia Minor.

During the early part of their history, the Romans were not in advance of other nations in the utilization of the metal lead, but with the growth of the empire it gradually came into more extensive use, until at last it was applied to almost every purpose for which it is employed at the present day.

At the close of the Punic War, as we have seen already, the valuable mines which had been exploited by the Phoenicians in Sardinia and Spain came into their possession, and somewhat later the famous mines of Laurion in Attica.

Most of these mines were, however, worked rather for the silver which the lead contained than for the lead itself, although even under those circumstances the production of the latter metal must have been considerable.

But with the occupation of Britain vast supplies were at once available from the rich ores which abounded there even at the surface of the ground in several localities, so that from about the first century of our era began that lavish use of lead for which the Romans became specially noted.

The Sardinian lead mines must have been very vigorously carried on by them, as the accumulations of slag mixed with Roman remains in the province of Iglesias are of such enormous extent that for many years they have furnished material for the extraction of lead and silver to the smelting works at Domusnovas, Cagliari, and several other places in the province.

The lead mines in Spain, until the discovery of those in Britain, were the most valuable in the ancient world, in Roman, as in Phoenician times, not even excepting the famous mines of Laurion.

The most important of the Roman mines were in the southern part of the Spanish peninsula, but others of considerable extent were also worked near Barcelona, and the hill district of Asturias. The chief seat of the lead and silver mining industry was Carthagena. Here and in the vicinity, and at Linares and Almeria, and even further westward, there are numerous vast heaps of ancient slags, chiefly Roman.

Other interesting relics of Roman lead smelting in the country are figurines of lead, fifty of which were found near Orihuelva (Valencia). One of these is in the Museum of Practical Geology.

Several other localities, in addition to those enumerated, are noted by ancient writers, but it has not yet been possible to determine their sites from existing remains.

As regards the two famous mines mentioned by Pliny,[1] the Santarensian and

[1] Pliny, *Naturalis Histori*, xxxiv, 17, 49.

the Antonian mine in Baetica, there can be little doubt that they were situated in the mining region between Carthagena and Almeria or near Linares, as there are no accumulations of mining and smelting debris in any other districts, which, in any way, correspond with the extent of their operations as recorded by Pliny.

The lead mining operations of the Romans in Gaul, judging from the metallurgical remains which have come down to us, and the evidence afforded by ancient excavations were conducted on an insignificant scale. The ores were not only much less abundant, but their mode of occurrence was also less favourable than in the Spanish peninsula.

Pigs of lead, bearing the names of the Emperors Nero, Hadrian, and Septimus Severus, have been unearthed respectively at Vieil, Evreux (Dept. Eure) Lillebonne (Dept. Seine Inferieure), and Chalons-sur-Saône (Dept. Saône-et-Loire). These localities are far distant from any lead mining district, and as the pigs closely resemble those found in England, Abbé Cochet hence attributes them to Shropshire.

The importance of Britain to the Romans as a lead-producing country is indisputably proved by the extensive mining excavations, and the vast quantities of mining debris and metallurgical *residua* which they have left in the chief ore-bearing districts, also by the number of pigs of lead, bearing imperial and other Roman names, which have been found either at the mines or on the roads leading from them.

The most important centres of Roman mining were:—the Mendip Hills (Somersetshire); the district of the Stiperstones and its subsidiary hills (Shropshire); the hill region of North Derbyshire; and the neighbourhood of Holywell (Flintshire).

More than fifty Roman pigs of lead have been found in Britain, either in the neighbourhood of the ancient mines where they were produced or near the roads leading from them to Roman stations. This large number, all of which may be regarded as having been accidentally lost, taken together with the vast extent of the Roman mining excavations and accumulations of slag and other debris, indicates in a very forcible manner that the production of lead in Britain during the Roman occupation must have been exceedingly great.

These pigs were found near, or can be traced to, the following mining centres:—

Somersetshire. Eight pigs, the earliest bearing the name Britannicus (A.D. 44 to 48–9).

Shropshire. Four pigs, all bearing the name of the Emperor Hadrian (A.D. 117 to 128).

Flintshire. Twenty-eight pigs, the earliest bearing the name of the Emperor Nero (A.D. 60 to 68).

Derbyshire. Ten pigs, the earliest having the name of the Emperor Tiberius Claudius (A.D. 44).

The most extensive applications of lead that had yet been made in the history of the metal were those that arose out of the elaborate systems for the supply and

distribution of water in cities and the construction and equipment of baths, which formed such an important feature in the social life of the Romans.

The chief forms in which it was used for these purposes were sheets and pipes. The former, of which numerous specimens have come down to us, were of very varying dimensions, ranging from the small strips unearthed at Silchester, barely thicker than paper, to the large and ponderous plates which were used in the construction of the baths at Bath, which are nearly $\frac{5}{8}$ inch in thickness.

The water pipes varied from 2 or 3 inches to 18 inches in diameter. They often bear inscriptions, which are always in relief, and were formed on the sheet of which the pipe was made by casting it in a stamped mould, as was the case with the pigs. The inscriptions consist generally of the name of the Emperor, the officer having charge of the regulation of the water supply, the plumber, and often the owner of the house.

They sometimes indicate, too, that the water was an imperial concession. Amongst the plumbers it is interesting to note a number of female members of the craft.

As a material in construction, we find it sometimes run into the joints of masonry as a binding substance, also as dowels, and for fixing metal clamps and plaques to blocks of stone. Bronze statues which were imperfect castings were repaired with lead. Others had their stability increased by filling their bases with the metal.

A noteworthy use was the construction of coffins. A considerable number of these have been dug up from time to time, both in our own country and in France; a few only survive, the others having been consigned to the melting pot.

Lead was also largely used as a constituent of pewter and solder and for most purposes for which it is employed at the present day.

For these needs vast quantities were required, and hence it was that the mines of Spain and Gaul, but more especially those of Britain, were worked with such assiduity and perseverance.

Iron.

The belief held by some archaeologists that the first iron known to man was either of meteoric origin or telluric native iron is not supported by any substantial evidence. It is true masses of telluric iron occur at Ovifak in Greenland and have afforded the Eskimo, as we have already seen, material for tools and weapons. Also the doubtful meteoric iron of the Toluka Valley in Mexico is worked there into axes and other implements.

But in the few other localities where telluric iron has been found in basalt and other rocks the metal occurs in grains or in nodules too small for practical use, and in three cases contains from 65 to 75 per cent. of nickel.

The rare occurrence of iron, either meteoric or telluric, further the impossibility of detaching pieces suitable for working from almost all meteorites by means of stone or bronze tools, is opposed to the belief that such iron was the material used by the men of the Early Iron Age.

Further, the assumption which is sometimes made that one or other of these forms of iron must have been the earliest source of the metal is not only without any solid foundation, but is totally unnecessary, for, as will be shown below, iron ores are so easily reducible that they can be converted into metallic iron in an ordinary wood or charcoal fire.

From the foregoing remarks I think it will be evident that native iron, whether of meteoric or telluric origin, can have played no part in the rise and development of the Iron Age.

The view held by some that meteoric iron is not malleable and hence could not have been utilized is, however, untenable, as, according to the researches of Dr. Beck, out of 70 iron meteorites (siderites) 48 were malleable whilst only 7 were absolutely unmalleable.[1]

The discovery of the metal iron, in my opinion, arose either from pieces of rich iron ore becoming accidentally embedded in the domestic fire, the burning embers of which would easily reduce them to the metallic state, or it may be from primitive man having already obtained the metal copper from certain stones experimenting with others in the same manner in his rude furnaces, when, if these consisted of iron ore, lumps of malleable iron would certainly be produced.

So easily, in fact, is the metal iron reduced from its ores that it is extremely strange that it was not the first metal discovered by neolithic man.

It has been and is still asserted by some archaeologists, owing to an imperfect acquaintance with metallurgy, that the extraction of iron from its ores requires a greater knowledge than the extraction of copper, also that a higher temperature is required for the former than the latter operation. Both statements are in direct contradiction to the facts established by practical metallurgists—

1st. That there is no simpler process than the production of malleable iron from its ores in a charcoal fire.

2nd. That the temperature required for the reduction of iron is only 700° to 800° C., whilst that required for copper is not less than about 1,100° C.

Moreover, as we shall see later, neither bellows nor an artificial blast of any kind is necessary.

No fusion is required in the case of iron as in that of copper; the metal is obtained as an unfused malleable lump, which only needs hammering to fashion it into implements or weapons.

The distinguished metallurgist the late Dr. Percy has so ably stated the metallurgical view of this question in his book "Iron and Steel"[2] that I will quote the passage *in extenso.*

"From suitable ore, of which abundant and readily accessible supplies exist in various localities, nothing more easy can be conceived than the extraction of malleable iron.

[1] Beck, *Geschichte des Eisens*, p. 26.

[2] Dr. Percy, *Metallurgy, Iron and Steel* (London, 1864), p. 873.

"Of all metallurgical processes it may be regarded as the most simple.

"Thus, if a lump of red or brown hæmatite be heated for a few hours in a charcoal fire, well surrounded by, or embedded in, the fuel, it will be more or less completely reduced, so as to admit of being easily forged at a red heat into a bar of iron.

"The primitive method of extracting good malleable iron directly from the ore, which is still practised in India and in Africa, requires a degree of skill very far inferior to that which is implied in the manufacture of bronze."

The erroneous belief which is still too prevalent among archaeologists even at the present day, that fusion is necessary for the extraction of iron is evidently founded on the modern method of iron smelting, by which cast iron is first produced and subsequently converted by special processes into malleable iron or steel. This, in spite of the fact that this method only dates from the fifteenth century, when high furnaces and high pressure of blast were introduced by which alone cast iron can be produced.

It should be a matter of common knowledge that, before that date all iron was obtained as malleable iron direct from the ore and was never molten but accumulated as a metallic mass at the bottom of the furnace and had to be removed mechanically. No other procedure was possible with the low furnaces or hearths, which were the only appliances then available. The metallic mass was practically infusible and consisted of grains of wrought or malleable iron of a steely nature and could be readily forged into any required shape.

The evidence afforded by the remains which have been found on the old iron sites proves, I think, incontestably that the actual process for the extraction of iron from its ores in Europe, in fact, in all countries, in early times was everywhere practically the same; it was only in the furnaces and appliances that differences occurred. Moreover, the process was one of the simplest in the whole range of metallurgy, whether the furnace cavity was a simple hole in the ground or prolonged above it. The fuel was charcoal, and this was placed in the furnace, and sometimes also piled above it, in alternate layers with the iron ore. The fire was urged either by the wind alone or by a blowing appliance of some kind to the temperature necessary for the reduction of the ore to metallic iron.

I have again to repeat and emphatically, as so much misconception exists on this point, that the metal was never melted but was always obtained in the form of a solid, sometimes spongy mass of infusible malleable iron, occasionally of a steely character.

No elaborate appliances or tools were needed for the operations. Even at the present day in Ceylon the bloom or mass of iron is taken out of the furnace with long tongs made of green wood sticks tied together at one end and is then beaten a little into shape with thick sticks. In Africa the stem of a creeper is employed for the same purpose, and the bloom is then hammered into shape with a stone, a larger stone serving as an anvil.

The prehistoric process still is practised in Africa, and in a modified form in

India in the Deccan, Central and North-Western Provinces and in other localities, and in Borneo; in Europe, in the province of Catalonia in the north of Spain and in Finland.

In Plate XXVII, Fig. 1,[1] is represented the removal of the mass of iron from a furnace in Catalonia.

In Japan, the furnace which still survives has no parallel in its simplicity, rudeness, and temporary character. Even the earliest furnaces of Europe, so far as we can infer from their vestiges which have been unearthed, were of a more advanced type than it. It consists simply of a V-shaped trough of common clay with holes near the bottom for the introduction of the blast. The furnace is charged with alternate layers of charcoal and ore during about fifty or sixty hours, after which the sides are so much fused and corroded that the operation is stopped, the walls are broken down and the masses of reduced iron containing steely portions removed by levers and bars and broken up when cold. The steely fragments are separated and from them the famous swords of old Japan were made.

A new furnace is at once constructed on the old site and is ready for work in about 24 hours.

From the foregoing, the simple character of the operation necessary for the production of iron in a malleable condition from its ores is clearly manifest.

As regards cast iron the furnaces, until mediæval times, were too low, and the blast insufficient for its production, it is not impossible, however, that it might sometimes have been obtained in small quantities when the temperature of the furnace was abnormally raised by a violent wind or an accidental increase in the blast and when at the same time an excess of charcoal was present. It could, on the other hand, never have been utilized, as on account of its brittleness it could not be hammered into any useful form and on account of its very high melting point it could not then be remelted and cast.

If it was ever produced, it must have been returned to the furnace with the next charge, as no specimen of early date has yet been found.

It is important to note here that the type of furnace which still survives in India among the hill tribes of the Ghats is closely analogous to the prehistoric furnaces of the upper basin of the Danube, Fig. 5,[2] and of the Jura district in Europe. It consists simply of a cylindrical shaft of clay about 10 to 15 inches in diameter and 2 feet 6 inches to 4 feet in height, with an aperture near the base for the admission of the blast and withdrawal of the iron and another for the exit of the slag. I append a brief description of the working of a charge as the furnaces of prehistoric times must have been worked in the same manner. "The furnace is first filled nearly half full of charcoal and upon this, fire is put, after which it is filled to the top with charcoal. The blast is then applied. When the charcoal sinks at the top of the furnace, alternate charges of ore and charcoal are supplied until the proper charge of ore has been introduced, after which the blast is

[1] Reproduced from Percy, *Iron and Steel*, p. 283, by permission of Mr. John Murray.

[2] *Jour. Iron and Steel Inst.*, 1897, vol. lii, p. 205.

increased and maintained till the close of the operation. The greater part of the slag remains in the furnace and is taken out along with the iron. In from four to

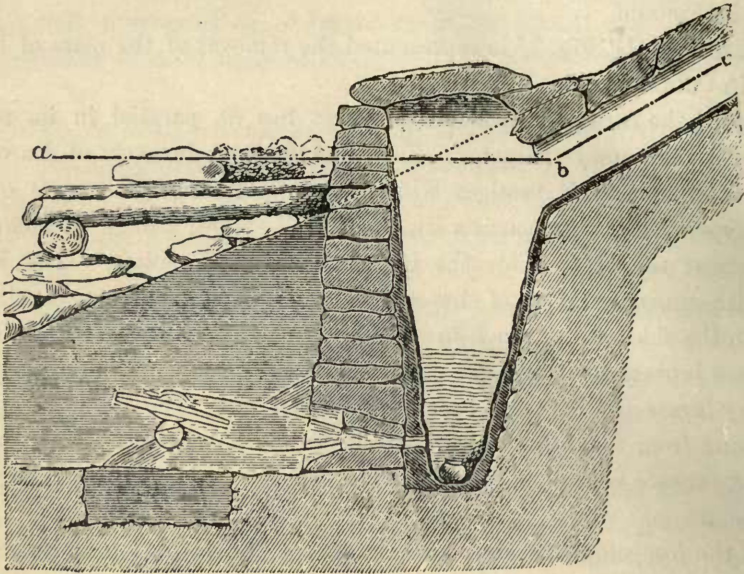

FIG. 5.—ANCIENT IRON SMELTING FURNACE, GYALAR, TRANSYLVANIA.

six hours a charge is completed, when the front of the furnace being removed a small mass of malleable iron, slag and unburnt charcoal is drawn out." The iron is then hammered into a bar.

In Upper Burma a furnace, Fig. 6,[1] of the same type as those still survived

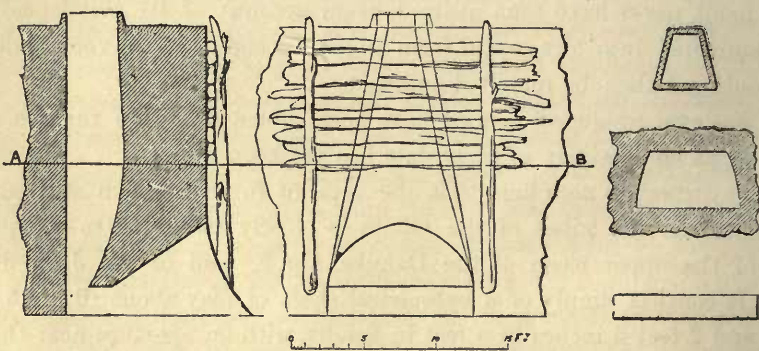

FIG. 6.—IRON SMELTING FURNACE. BURMA.

in 1864, but in the mode of working it was even more primitive, as no artificial blast whatever was made use of. During working, the air necessary for the combustion of the fuel was admitted through a number of clay tubes clayed into the aperture through which the mass of iron was drawn out after the operation. No care appeared to be taken in selecting localities where a natural blast might be obtained by making the furnace to face the prevailing wind.

[1] Reproduced from Percy, *Iron and Steel*, p. 272, by permission of Mr. John Murray.

Early iron smelting localities.—In Western Asia there are two important districts where iron ores are of very extensive occurrence and in which remains of early iron manufacture are found.

One is the region on the south-east of the Euxine (ancient Paphlagonia and Pontus), extending from the modern Yeshil Irmak to Batum, and comprising a series of mountain ranges, not far from the coast, along the lower slopes and foot hills of which the iron deposits are scattered.

The other is the Taurus and Anti Taurus region on the south-east of Asia Minor, extending on the West from Cape Anamur to the borders of Syria and in Syria to Aleppo, the Euphrates and Lebanon.

Either of the above sites might have been the earliest for the production of iron in Western Asia, but from a metallurgical point of view, deduced from the extent and character of the ancient remains, there are strong reasons for believing that the first-mentioned region was the first in which the metal was regularly produced.

Iron ore is also found in the Tiyari Mountains to the north-east of the site of Nineveh and in the neighbouring part of Kurdistan and is a source of iron at the present day.

It may be that the ore of the Tiyari Mountains was also treated by the ancient Assyrians for the extraction of iron at a very early period, but either the ore was difficult to work or yielded insufficient or inferior metal, for as early as 881 B.C. the metal was brought to Assyria as tribute from the iron district of the Euxine, the country of the Chalybes, Tibereni, and Moschi of classical writers.

It is also recorded that Ashur-nasir-pal (885 to 860 B.C.) obtained iron in the neighbourhood of Carchemish. In support of these records which testify to the extensive use of iron by the Assyrians we have the remarkable find of Victor Place at Khorsabad. There in the ruins of the palace of Sargon, built about 710 B.C., he found a storehouse containing, according to his estimation, not less that 160,000 kilograms of iron. The greater part consisted of iron bars from 12 to 19 inches in length, and $2\frac{3}{4}$ to $5\frac{1}{2}$ inches in thickness. They were roughly drawn out at each end and pierced with a hole, as shown in Fig. 7,[1] and weighed from about 9 to 44 lbs. Place supposed them to be work tools of some kind, but they are really bars of iron forged at the furnace of the mines into this shape for convenience of transport by men, horses, or camels.

It is worthy of note here that similar forms survived for iron for transport and trading in Roman times and even up to thirty or forty years ago in Finland and Sweden.

The collection was chiefly a store of unworked iron held in readiness by the king for the instruments of war and for building construction. It contained also, however, many kinds of finished iron articles, such as chains, horse bits, etc., all arranged in regular order.

This vast accumulation of iron indicates incontestably that the metal had been in use for many centuries previous to the time of Sargon, so that it will not

[1] Reproduced from Beck, *Geschichte des Eisens*, p. 135, by permission of F. Vieweg and Sohn.

be unreasonable to assume that the Assyrians were acquainted with iron certainly earlier than 1500 or even 2000 B.C.

Layard also, as is well known, found in his excavations on the site of Nineveh many weapons, swords, daggers, lance-heads, arrow-heads, and tools of iron.

Other districts in North Asia where the metallurgy of iron was practised in remote times are as follows :—

In Northern Persia, in the neighbourhood of Parpa, between Kerman and Shiras and not far from Persepolis, there are extensive remains of early iron workings which were doubtless the source of the vast numbers of iron implements and objects found on the plain in the vicinity of that ancient city.

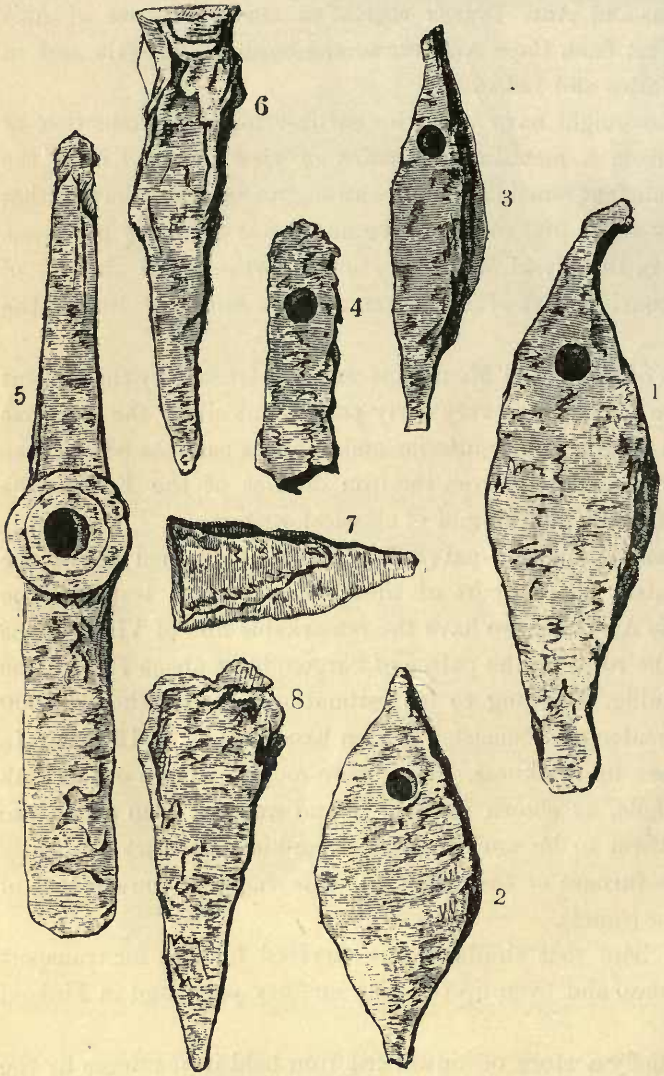

FIG. 7.—IRON FOUND AT KHORSABAD.

Also in Northern Persia in the Karadagh district mounds of prehistoric iron slag of enormous extent have been found.

From these districts, in addition to those mentioned, Nineveh also obtained some iron.

In India iron ores are somewhat widely distributed, and have been worked in very early times, chiefly in the North-Western Provinces, Central India, the Western Ghats, Mysore, Madras, Haiderabad, Kutch, and elsewhere.

It is extremely probable that iron was extracted from them at least as early as the tenth century B.C. in Southern India, and at a much earlier date in the Punjaub, as the metal is said to be mentioned in the Rig-Veda as in use for weapons.

In other parts of the world, as Egypt, Western Asia, and Europe, generally a Copper or Bronze Age had preceded the Iron Age, but the existence of such an

era in Southern India has yet to be proven. Bronze, brass, and copper implements and ornaments have indeed been found in a few instances, but apparently none as yet under circumstances showing distinctly that they preceded the Iron Age.

According to Pliny the best steel was that of Serica, but what country is indicated by that name has not yet been definitely determined. It is extremely improbable that it was China, and we must rather regard the mountain district of Ferghana (Khokand) as the source of Serican steel (Beck).[1] In Chinese annals it is recorded that a prince of Khotan had presented one of the kings with a writing case of " blue iron," doubtless meaning steel. Iron ores are of common occurrence in China, chiefly in the Western Provinces, but there is no concrete evidence to show how early they were worked for the metal.

As to the time of the first use of iron the evidence, too, afforded by the ancient literature is of a very doubtful character. In the Shu-King to which the date 2000 B.C. has been attributed, iron is indeed mentioned, but with this exception—there is no allusion to iron in writings older than about 1000 B.C. (Edkins).

The magnetic compass, however, is said to have been invented by the Chinese at a very remote date, earlier than 1000 B.C., and if so they must then have been acquainted with steel.

The Japanese when they migrated from the mainland were passing out of the Bronze Age stage of culture and entering the Iron Age, as but few weapons of bronze, only halberds and one or two swords, have been found, and these only in those parts of the islands which were first occupied by them. They had already become skilful workers in iron before they became dolmen builders, three or four centuries B.C. No weapons except iron swords, spear-heads, and arrow-heads have been found in the chambers of the dolmens, and all, more particularly the swords, are splendid examples of the work of the smith.

The much disputed question as to the time when iron was first used by man requires our consideration as far as the available evidence will permit. In this connection it is almost unnecessary to point out that the evidence is not only very imperfect, but is also unfortunately in too many cases, especially that based on philology, liable to misinterpretation, hence the question does not admit at present of a decisive answer. However, based on such evidence as is available, the dates given in the following table have been advanced with more or less authority for the discoveries and events to which they are respectively prefixed.

TABLE.

Pre-dynastic times in Egypt. Iron beads.

IVth	dynasty	3733 B.C.	A piece of iron in an inner joint of the Great Pyramid at Gizeh.
Vth	„	3566 „	Several pieces of a pickaxe from Abusir.
XIIth	„	2466 „	A spear-head, Nubia.

[1] Beck, *op. cit.*, p. 255.

	About 2357 B.C.	Iron in use in China according to recent researches in early Chinese history (Brough).
XVIIIth dynasty	1600 to 1400 B.C.	A sickle, Karnak.
	About 2000 B.C.	Pieces of iron in the Second City, Hissarlik.
	„ 1500 „	Iron knife found by Schliemann at Hissarlik.
	„ 1400 to 1300 B.C.	Achæans enter Greece and, according to Ridgeway, had iron swords.
	„ 1200 B.C.	The Bronze Age shades off into the Iron Age in Crete.
	„ 1100 „	Iron implements at Villanova, North Italy.
	„ 1100 „	Iron in use in Etruria (Montelius).
	„ 1000 „	Iron Age in Greece in the Homeric period.
	„ 885 to 860 B.C.	Ashur-nasir-pal brought iron from Carchemish.
	„ 881 B.C.	Assyria, tribute lists of Moschi.
	„ 800 „	At the destruction of Damascus 5,000 talents of iron were taken.
	„ 800 „	Iron swords in Central Europe (Montelius).
	„ 800 „	Iron Age in Britain (Montelius).
	„ 700 „	Vast numbers of iron implements and trading bars in Sargon's palace.
	„ 700 „	Iron weapons (Hallstatt).

On a perusal of the above table the conflicting and irreconcilable character of many of the dates will be seen to be a striking feature.

From a metallurgical point of view several of the attributions of date appear to be not only inexplicable but highly improbable.

Accepting the dates given for the Egyptian specimens as approximately correct, whence came the few early pieces of iron mentioned above.

The specimen from the Greek Pyramid was examined by Flight and pronounced to be non-meteoric, further, it contains combined carbon, and for that and other reasons, already previously mentioned, can hardly be telluric. I hence think it is not altogether impossible that it came from the Sinaitic peninsula, and was obtained there by the accidental treatment by the copper smelters of the rich iron ore which crops out near the veins of copper ore. If this was so the question arises, did the production of iron continue to be carried on there from that time.

In somewhat later times, if we may reason from the heaps of ancient iron slags, Egypt undoubtedly obtained some of its iron from that region.

The rarity of the occurrence of iron implements and weapons in Egypt, up to comparatively late times is inexplicable in view of the intercourse between that country and Assyria, where the metal was certainly in use as early as about 1500 B.C. It is, however, well to remember in this connection that neither have

implements of bronze been found in the numbers that might be expected when we consider the extensive works in Egypt, which could hardly have been accomplished without a metal. As regards the working of stone, in which the Egyptians were especially expert, but few tools suitable for the purpose have been found. These facts would almost lead us to believe either that stone tools were employed or that iron tools may some time be discovered.

In Africa, so far as metallurgical evidence may be relied on, the extraction ot iron from its ores was carried on at a very remote date. The seats of an ancient iron industry, marked by accumulations of slags and debris, are so widely distributed in that continent that it must date from a very early period, and, according to Beck, must have been indigenous. That this early African iron smelting was known in Egypt is well shown by Figs. 8 and 9,[1] which are reproduced from bas-reliefs on a stone now in the Egyptian Collection in Florence.

In Fig. 8 a youth, whose head and outstanding ears characterize him as an Ethiopian, is working a drum-like skin bellows from which the blast of air is conveyed to a shallow hole, in which the ore is reduced to metallic iron.

In Fig. 9 we see the lump of iron, which was obtained, being forged on a stone anvil with a wooden base, with a hammer consisting of a stone or piece of iron held in both hands by the smith or "striker."

The date of the bas-reliefs is not known but bellows of precisely the same form are depicted on a wall painting in a tomb bearing the name of Thotmes III. (1503 to1449 B.C.).[2]

In Fig. 10[3] is reproduced a pen-and-ink sketch made by Capt. Grant, who accompanied Speke to Lake Nyanza, of the operation of making malleable iron direct from the ore in that region. The ancient process and form of bellows had thus survived there.

In the earliest times bellows were not used, neither were they necessary, as furnaces still exist and are at work at the present day at Ola-igbi, about 160 miles from Lagos, in which no artificial blast is employed, the wind alone supplying the air required.

From these facts it would follow that it is extremely probable that the sickle of the XIIth dynasty (2466 B.C.) found in Nubia had its origin in one or other of the African smelting sites.

In Assyria, as I have already pointed out, the Iron Age dates from a far distant period.

The records of tribute from the Moschi and the extremely large quantity of the metal found at Khorsabad indicate in my opinion an antiquity for its use which cannot be placed later than 1500 B.C.

On the south-east of the Euxine, the vast extent of the prehistoric slag heaps

[1] Reproduced from Beck, *Geschichte des Eisens*, 1*ste Abth.* p. 97, by permission of F. Vieweg and Sohn.

[2] Wilkinson, *Ancient Egyptians*, ii, 312.

[3] *Quart. Journ. of Sc.*, 1870, vol. vii, Plate, Fig. 1, p. 198.

which are scattered throughout the iron region of the ancient Pontus tend to show that at an even earlier date iron was then extracted from its ores.

As regards India, if the statements of the Rig Veda may be accepted, iron was in use in the Punjaub as early as 1500 B.C.

Further, lance-heads and objects of iron have been found in the graves and burial mounds of the Deccan before the influx of the Hindus; and in the old Indian graves near the Indus, to which the date 1500 B.C. has been ascribed, objects of the metal have also been found (Beck).

In Europe we are confronted with serious difficulties in the determination of the beginning of the Iron Age. Metallurgy would point to two centres, the

FIG. 8.—EGYPTIAN BAS-RELIEF REPRESENTING IRON SMELTING.

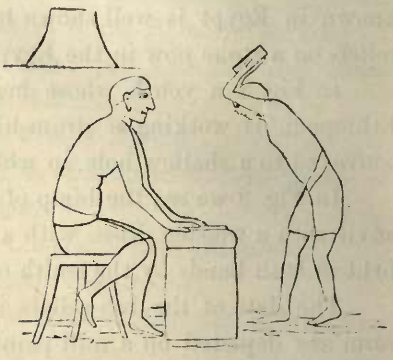

FIG. 9.—EGYPTIAN BAS-RELIEF REPRESENTING THE FORGING OF IRON.

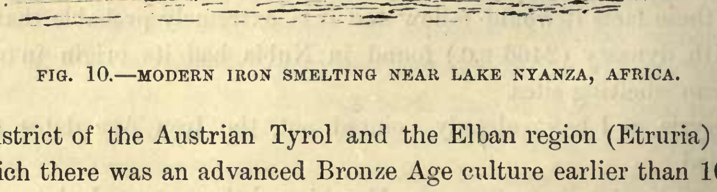

FIG. 10.—MODERN IRON SMELTING NEAR LAKE NYANZA, AFRICA.

Eisenerz district of the Austrian Tyrol and the Elban region (Etruria) of Italy, in both of which there was an advanced Bronze Age culture earlier than 1000 B.C.

From a purely metallurgical point of view iron was first produced in the former region, the country around the upper waters of the Danubian tributaries the Drave, the Save, the Mur, and the Enns (the ancient Noricum). We have there on many sites vast deposits of easily reducible iron ore, at Eisenerz so extensive that the entire mountain is one mass of pure iron carbonate and oxide. So abundant must lumps of the ore have been on the hillsides and in the beds of the streams, that they cannot have failed to have been used as the enclosing stones of the domestic hearths and as I have already pointed out if by chance any became

Ligna accenſa A. Ligna quibus utrinque ſunt tenuiſsimæ bracteæ aſſatæ B. Cuniculus C.

FIG. 1.—MINING BY THE AID OF FIRE.

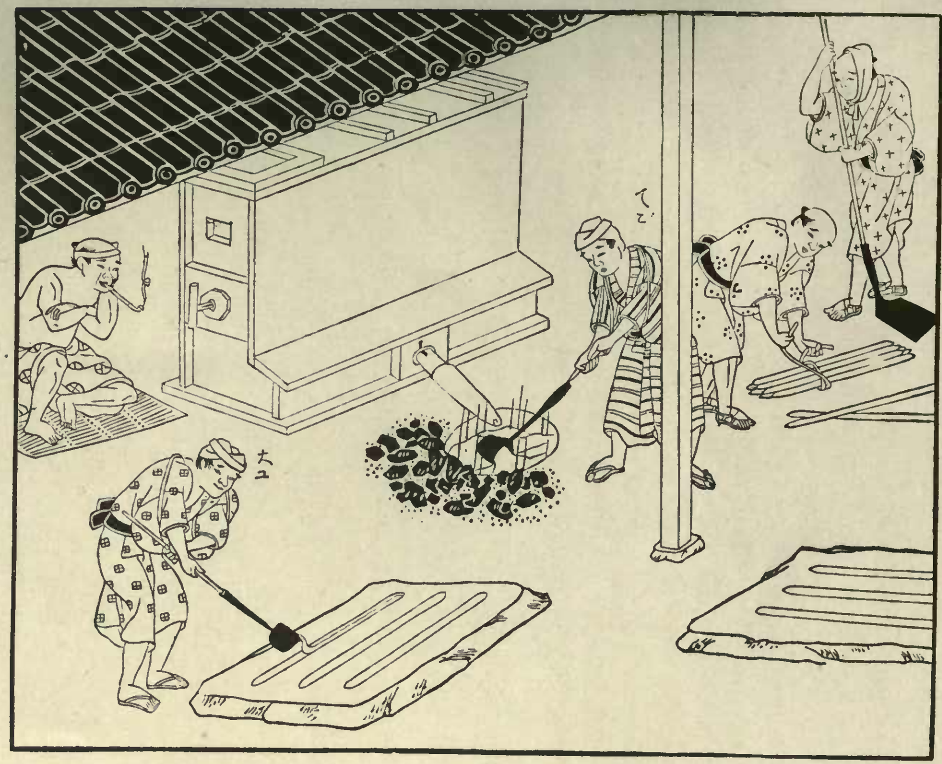

FIG. 2.—TIN SMELTING. JAPAN.

THE METALS IN ANTIQUITY.

Journal of the Royal Anthropological Institute, Vol. XLII, 1912, Plate XXVI.

PREHISTORIC CRUCIBLES.

THE METALS IN ANTIQUITY.

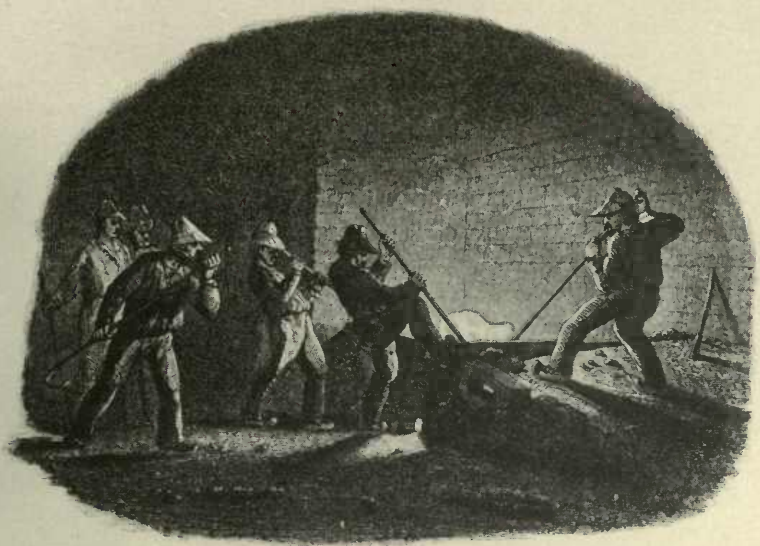

FIG. 1.—REMOVING MASS OF IRON FROM THE FURNACE. CATALONIA, SPAIN.

FIG. 2.—QUERNS USED FOR GRINDING GOLD ORE. FROM ANCIENT MINE, NUBIA.

THE METALS IN ANTIQUITY.

FIG. 1.—EXTRACTION OF SILVER FROM ARGENTIFEROUS LEAD BY CUPELLATION JAPAN.

FIG. 2.—GRINDING GOLD ORE IN A QUERN. JAPAN.

THE METALS IN ANTIQUITY.

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ROMAN BAS-RELIEF FROM LINARES, SPAIN.

THE METALS IN ANTIQUITY.

embedded in the fire malleable iron would be produced. No mining operations were needed, as the brown ores, which are the easiest to reduce, occur everywhere on the surface and it was these only which were treated by the early iron workers, the others being rejected and are now found in the waste heaps.

From an archaeological point of view, however, there is an anomaly that requires investigation.

If the Achaeans were in the Iron Age, when they entered Greece (1400 to 1300 B.C.), and they obtained their iron from Noricum, or from the ores near Glasinatz, it would seem that the iron weapons of the Hallstatt people of the same culture as those of Glasinatz should be given an earlier date than 700 B.C., which is usually assigned to them, Hallstatt being within easy distance of the prehistoric iron sites of Noricum.

In the Elban district, in the Proto-Etruscan period of Montelius, about 1000 B.C., iron swords with bronze handles are common. From the occurrence of such advanced weapons as swords it might be contended that iron had been in use for several centuries earlier, but this contention will not hold if we remember that the men of the Bronze Age had already become highly skilled as workers in metal, so that, when once they had obtained a lump of iron from its ore, they would have less difficulty in fashioning it into weapons, especially swords, than they had with copper or bronze. Hence, from the first discovery of iron until its general use, there would be no long interval of time.

From what has just been stated regarding these two districts, Noricum and the Elban region, it will be evident that further research is required before we can definitely ascribe to either the first extraction of iron from its ores in Europe.

Then, as regards Asia and Europe, I think there can be no doubt that, as is the case with copper, so with iron, it was in use in Asia before it was known in Europe.

Thrace has been supposed to be the site of early iron smelting, but of this there is no metallurgical evidence. Thracian swords were indeed famous in Homeric times, but it does not follow that, although the swords may have been made in Thrace, that the iron of which they were forged was obtained there, for it is well known that the metal for the noted Damascus blades of mediæval times was not made at Damascus, but at Kona Samundrum near Nirma in Haiderabad,[1] also that Sheffield steel is manufactured from Swedish iron.

[1] Schwarz, *Stahl und Eisen*, vol. xxi, pp. 209–399.

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